

**ANNUAL REPORT FOR
FEASIBILITY STUDIES
AT ROCKY FLATS PLANT
FISCAL YEAR 1991**

ROCKY FLATS PLANT

**U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden Colorado**

ENVIRONMENTAL RESTORATION PROGRAM

March 1992

**ANNUAL REPORT FOR
TREATABILITY STUDIES
AT ROCKY FLATS PLANT
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ENVIRONMENTAL RESTORATION PROGRAM

March 1992

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EXECUTIVE SUMMARY

The Annual Report on the Treatability Studies at Rocky Flats Plant (RFP) summarizes the results and progress of the Treatability Studies Program within the Environmental Restoration (ER) Program for Fiscal Year 1991, October 1, 1990 through September 30, 1991. The ER Program is a comprehensive effort consisting of site characterization, remedial investigations, feasibility studies and remedial/corrective actions to address environmental contamination at the RFP. These activities are pursuant to the Inter-Agency Agreement (IAG) developed among the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Health (CDH).

The Final Treatability Studies Plan (TSP) was issued in August 1991 and was developed in accordance with Article XI of Attachment 2 of the IAG. The Final TSP evaluated candidate remedial technologies for various types of contamination identified at RFP. The sitewide treatability study program is intended to address technologies applicable to remediation efforts at two or more operable units (OUs) at RFP and is separate from any treatability study testing which may be conducted as part of remedial actions at individual OUs. EPA/DOE correspondence and the Treatability Studies Plan outlined the requirement for annual reports on the Treatability Studies Program. Annual reports supersede the IAG requirements for a Final Treatability Study report in 1993. Annual reports will provide information on the current status of the program and briefly summarize any reports issued for individual treatability studies. Additional site characterization data for RFP will be reviewed and compared to Applicable or Relevant and Appropriate Requirements (ARARs) to determine if any changes in contaminants of concern have occurred. Annual reports will also review and revise the technology evaluation presented in the Final TSP to account for new information on site contamination data, ARARs, and innovative technologies.

The technologies were identified and screened in the Final TSP and Annual Report based on the potential for application to the following contaminant types present in soil, sediments, surface water, and groundwater: volatile organic compounds, semivolatile organic compounds, polychlorinated biphenyls (PCBs), inorganics, metals, and radionuclides. The semivolatile organic compounds and PCBs were identified as new contaminant categories for the Annual Report. The technologies which passed the preliminary screening were subjected to a final screening. The final screening determined if the technology should be included in the sitewide treatability test program at this time. Statements of Work (SOWs) were prepared for technologies selected for laboratory or bench-scale testing.

Four water treatment technologies including ozonation, peroxide oxidation, ultraviolet (UV) oxidation, and UV photolysis were identified for bench or laboratory scale treating with application to PCBs in surface water. This supplements the other technologies for surface or groundwater previously identified in the Final TSP, including ion exchange, oxidation/reduction, adsorption, potassium ferrate precipitation (TRU-Clear™) and ultrafiltration/microfiltration.

Soil/sediment treatment technologies were previously selected in the Final TSP for bench or laboratory scale testing and include physical separation, soil washing, the solidification/stabilization/fixation technologies, epoxy polymerization, polyester polymerization, portland cement, masonry cement, gravimetric physical separation (TRU Clean™), and magnetic separation. Slurry phase bioreactor treatment technology was identified in the Annual Report for possible pilot testing of PCB-contaminated soil/sediment. Ozonation and UV photolysis were identified for pilot testing of volatile organic compounds (VOCs) and semivolatiles in surface water and groundwater. These technologies will continue to be evaluated for suitability for pilot testing as part of the sitewide Treatability Program.

The Final TSP identified the chemical oxidation technologies ozonation, peroxide oxidation, ultraviolet oxidation, and ultraviolet photolysis for pilot testing treatment of VOC-contaminated groundwater/surface water. The evaluation and selection process in this Annual Report eliminated the peroxide oxidation and ultraviolet oxidation technologies from pilot testing as part of the sitewide program because bench and pilot testing of ultraviolet peroxide oxidation is in progress at OU1.

Treatability testing in progress for various OUs at RFP include technologies for treatment of radionuclides in soils and surface water, VOCs from groundwater and suspended solids from surface water. UV-oxidation tests for OU1 groundwater evaluated the removal of VOCs using ultraviolet light and hydrogen peroxide. Test results showed removal of VOCs from the aqueous phase. Analysis of the offgas showed that the VOCs may have been stripped versus destroyed. Further evaluation is being conducted to determine if this stripping occurs in full-scale equipment. An on-site operations test is planned for early 1992 as part of the OU1 Interim Remedial Action.

Testing for the removal of actinides by physical size separation from soils at OU2 was conducted using gravimetric separation in conjunction with wet/dry sieving and attrition or rotary scrubbing. Preliminary results suggest that particle size separation warrants further consideration for treatment of soils contaminated with radionuclides. Additional testing using different types of soils and chemical additions to wash water is needed to evaluate its applicability to RFP soils contaminated with radionuclides.

Treatability testing for OU2 included use of granular activated carbon (GAC) for removal of VOCs from contaminated groundwater. Coagulation/precipitation/filtration was evaluated for removal of suspended solids. Treatability tests for the removal of metals and radionuclides using GAC, ion exchange, chemical precipitation and adsorption were planned, but surface water collected for the testing did not contain sufficient concentrations of radionuclides to conduct these tests. Vacuum-enhanced vapor extraction has been identified for pilot-scale in situ testing for the removal of free-phase volatile organic compounds from the subsurface as part of an Interim Measure/Interim Remedial Action (IM/IRA) for OU2. In situ steam stripping is also being considered in the IM/IRA for pilot testing based on bench-scale testing being conducted at Lawrence Livermore National Laboratory. Dehalogenation and chemical oxidation have been identified for bench-scale testing.

Bench-scale testing for the Techtran (now known as the Colloid Polishing Filter Method) Technology was conducted on radionuclide-contaminated groundwater from RFP. Eight tests were conducted and evaluated, based on removal of radioactive tracers. Bench-scale tests at RFP were conducted on surface water collected from OU4 and based on the results, a demonstration test will be conducted at RFP. A series of new bench tests will be repeated to provide more data for implementing the demonstration program at OU4 in 1992.

Work plans to test physical separation and magnetic separation processes for removal of radionuclides from soil and plans to test micro/ultrafiltration, oxidation/reduction and potassium ferrate precipitation processes to remove metals, radionuclides or organics from water will be completed in Fiscal Year 1992.

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ACRONYMS AND ABBREVIATIONS

Am	Americium
AnBAC	Anaerobic Biological Activated Carbon
ARAR	Applicable or Relevant and Appropriate Requirements
ATTIC	Alternative Treatment Technology Information Center
AWQC	Ambient Water Quality Criteria
BDAT	Best Demonstrated Available Technology
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
CMFS	Corrective Measures/Feasibility Studies
CTMP	Comprehensive Treatment Management Plan
DMSO	Dimethyl Sulfoxide
DOE	Department of Energy
EDTA	Ethylenediaminetetraacetic Acid
ELM	Emulsion Liquid Membranes
EM	Environmental Management
EPA	Environmental Protection Agency
ER	Environmental Restoration
FFCA	Federal Facility Compliance Agreement
GAC	Granular Activated Carbon
GPM	Gallons Per Minute
HEA	Health Effects Assessment
IAG	Inter-Agency Agreement
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
IM/IRAP	Interim Measure/Interim Remedial Action Plan
IR	Infrared Radiation
IRA	Interim Response Action
IRAP	Interim Remedial Action Plan
ISV	In Situ Vitrification
ITPH	Interceptor Pump House
IWT	International Waste Technologies
KPEG	Potassium Polyethylene Glycol
LDR	Land Disposal Requirements
LLNL	Lawrence Livermore National Laboratory
LPDE	Low Density Polyethylene
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDL	Minimum Detection Limit
NTIS	National Technical Information Service
O&M	Operations and Maintenance
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PACT	Powdered Activated Carbon Treatment
PCB	Polychlorinated Biphenyls
pCi/l	Picocuries per Liter
PEG	Polyethylene Glycol

ACRONYMS AND ABBREVIATIONS (Concluded)

PQL	Practical Quantitation Limit
PSI	Peroxidation Systems, Inc
Pu	Plutonium
Ra	Radium
RCRA	Resource Conservation and Recovery Act
RFEDS	Rocky Flats Environmental Data System
RFI	RCRA Facility Investigation
RFP	Rocky Flats Plant
RI/FS	Remedial Investigation/Feasibility Study
RI-CMS/FS	Remedial Investigation - Corrective Measures Study/Feasibility Study
ROD	Record of Decision
RTIS	Remedial Technology Information System
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SITE	Superfund Innovative Technology Evaluation
SO	Systems Operation
SOW	Statement of Work
SVE	Soil Gas Vapor Extraction
TBC	To-Be-Considered
TCA	Trichloroethane
TCE	Trichloroethylene
TCLP	Toxicity Characteristics Leaching Procedure
TDS	Total Dissolved Solids
TEA	Triethylamine
TIS	Technology Investment Strategy
TSP	Treatability Studies Plan
U	Uranium
UV	Ultraviolet
USCS	Unified Soil Classification System
VOA	Volatile Organic Analysis
VOC	Volatile Organic Compound
WERL	Water Engineering Research Laboratory
WQC	Water Quality Criteria
WQCC	Water Quality Control Commission
µg/l	Micrograms per Liter

INTRODUCTION

The Annual Report for Treatability Studies at Rocky Flats Plant (RFP) summarizes the results and progress of the Treatability Studies Program within the Environmental Restoration (ER) Program for Fiscal Year 1991, October 1, 1990 through September 30, 1991. The ER Program is a comprehensive effort consisting of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions to address environmental contamination at RFP.

The Final Treatability Studies Plan (TSP) was issued in August 1991 and was developed to evaluate candidate remedial technologies for various types of contamination identified at RFP. The sitewide treatability study program addresses technologies applicable to contaminants identified in two or more operable units (OUs) at RFP and supplements treatability testing which may be conducted for individual OUs. The Final TSP outlined the requirements for Annual Reports on the Treatability Studies Program.

The Annual Report reviews the current status of the program and summarizes the information available for individual treatability studies. Additional site characterization data for RFP are reviewed and compared to Applicable or Relevant and Appropriate Requirements (ARARs). The Annual Report reviews, reevaluates, and rescreens the technologies presented in the Final TSP to account for new information on site contamination data, ARARs, new information on previously identified technologies, and innovative technologies.

The Annual Report provides a mechanism to support the Remedial Investigation/Feasibility Study (RI/FS) and other programs and to transfer and share information and results of treatability testing for those programs they support. The following sections outline the objectives of the report in reviewing and presenting new data, information, and results.

1.1 NEW SITE CHARACTERIZATION DATA

To identify changes in the RFP characterization, new site characterization data from the Rocky Flats Environmental Data System (RFEDS) were reviewed. This included inputs to the RFEDS database since the development of the Final TSP, validated and corrected data, and new data from recent sampling and analytical testing programs. New contaminants and changes in the maximum and minimum contaminant concentrations were identified for surface water, groundwater, soils, and sediments.

The site characterization data were reviewed to identify if contaminant concentrations in specific media were greater than ARAR values in two or more OUs for screening and evaluation in the Annual Report. If ARAR values were exceeded in only one OU, the containment group was not included in the Annual

Report and will be addressed in the feasibility studies for the particular OU. Previous summary tables presented in the Final TSP were reviewed and updated for this report.

1.2 REVIEW OF ARARs

An RFP summary of possible and potential sitewide chemical-specific ARARs including Groundwater Quality Standards, Federal Surface Water Quality Standards, Statewide and Basin Surface Water Quality Standards, and Stream Segment Surface Water Standards was reviewed and updated for the Annual Report. The revisions were based on the review of additional site characterization data from RFEDS, the review of new state regulatory standards for groundwater and surface water, and corrections to tables used for the Final TSP. The development of possible and potential sitewide ARARs provides a preliminary list of remediation goals for the development of feasibility assessments and studies. These goals serve to develop alternatives for remedial technologies for particular contaminants and media at RFP. The ARARs listing will continue to be reviewed and refined.

1.3 TREATABILITY STUDY PROJECTS

The Annual Report summarizes treatability studies, interim reports, and other information from research studies available since the Final TSP was issued in August 1991. This information is considered in the review of the treatability technology selection process for future bench-scale and pilot-scale testing and reevaluation of previously selected technologies. Future treatability testing projects for individual OUs and the sitewide program are also discussed.

1.4 SCREENING AND SELECTION OF TECHNOLOGIES

The technology selection completed in the Final TSP was reviewed, reevaluated based on additional data, and expanded for the Annual Report. The site characterization data were reviewed and compared to updated ARARs values to identify major contaminant types and associated media that are present at RFP. A literature search was conducted to identify new, innovative, or emerging technologies for consideration in the screening process. This literature search also compiled new information presently available for review on technologies previously considered in the Final TSP.

Technologies were reviewed, reevaluated, and screened using a two-step process. The preliminary screening process associates technologies with major contaminant categories and their applicability to RFP. The criteria used in the preliminary screening process include applicability, removal efficiency, potential to meet the cleanup goal, technology maturity, operations and maintenance (O&M) requirements, implementability, and adverse impacts.

The final screening process evaluated significant advantages and compared proven technologies to determine if they should be included in the sitewide Treatability Studies Program. This included

effectiveness, cost, O&M, and reduction in adverse impacts. This final screening for inclusion of technologies in the sitewide Treatability Studies Program for bench and pilot-scale testing will be reevaluated in each Annual Report. Information on the cost of pilot-scale treatability testing was developed for the selected technology. New Treatability Statements of Work (SOWs) were developed for new technologies selected for the sitewide Treatability Studies Program.

1.5 ANNUAL REPORT ORGANIZATION

This first Annual Report on Treatability Studies is divided into five sections and four appendices. Section 1.0 provides an introduction and Annual Report objectives. Section 2.0 presents and reviews new site contamination data and ARARs, and describes the literature search for new information on technologies. Section 3.0 summarizes the status of treatability studies at RFP and future treatability testing. Section 4.0 presents the procedures used to review the technology selection and the results of the review. Section 5.0 lists the references reviewed in developing this document.

Appendices include Appendix A - Potential Applicable or Relevant and Appropriate Requirements (ARARs) for the Sitewide Treatability Studies Program, Appendix B - Technology Data Summaries for Groundwater/Surface Water Treatment Technologies Reviewed in the Annual Report, Appendix C - Technology Data Summaries for Soil/Sediment Treatment Technologies Reviewed in the Annual Report, and Appendix D - Statements of Work for New Technologies Selected for Treatability Tests.

NEW TREATABILITY STUDY INFORMATION

This section reviews new site contaminant data, ARARs, and additional literature for revising, updating and expanding screening tables previously completed in the Final TSP. New analytes at concentrations greater than possible and potential ARARs must be found in two or more OUs to be included in sitewide treatability studies. If ARARs values were exceeded in only one OU, the particular contamination was not considered in the Final TSP or Annual Report but will be evaluated in feasibility studies for the particular OU.

2.1 SUMMARY OF NEW CONTAMINANT DATA

To update the contaminant data in the Annual Report, maximum concentrations that were reported in the August 1991 Final TSP were reviewed against maximum values obtained from the RFEDS computer database. In many instances, this updating has resulted in increases in the maximum values reported in Table 2-1. This is not necessarily due to actual increases in contamination levels, but results from updating data that previously existed but had not been input to RFEDS. For a few analytes, such as calcium in groundwater, surface water, and soils, maximum concentrations shown in Table 2-1 were reduced from those previously reported in the Final TSP (Table 4-2). Some values used in the Final TSP were taken from draft reports or were considered preliminary. These data were subject to change following finalization of the reports or validation of the data. The data used to update maximum concentrations in Table 2-1 were extracted from RFEDS, prior to January 1992, and are also subject to change based on revisions to the database.

A number of new analytes are reported in Table 2-1. These include maximum and minimum values in the following categories:

- Metals category
 - Boron (groundwater)
 - Phosphorous (groundwater, surface water, sediments)
- Anions
 - Orthophosphate (groundwater, surface water)
 - Phosphate (groundwater, surface water)
 - Total Kjeldahl nitrogen (surface water)
 - Total organic carbon (surface water, soils)

- Radionuclides
 - Plutonium (Pu) 238 (groundwater, surface water, sediments)
- Volatiles
 - Bromoform (groundwater, surface water)
 - Dibromochloromethane (surface water)

Plutonium has historically been reported as Pu 239, 240. The recent appearance of Pu 238 in the RFEDS database is being investigated.

The largest number of new analytes were found in the semivolatiles category. New compounds listed in Table 2-1 that have been identified for the Annual Report include acenaphthylene, aldrin, alpha-BHC, alpha-chlordane, ametryn, atrazine, benzo(a)pyrene, benzoic acid, benzyl alcohol, beta-BHC, butyl benzyl phthalate, 4-chloro-3-methylphenol, 4-chlorophenyl phenyl ether, cyanazine, delta-BHC, dibenzo(a,h)anthracene, dibenzofuran, dicamba, 1,4-dichlorobenzene, dichloroprop, 2,4-dimethylphenol, 2,4-dinitrotoluene, endosulfan, ethyl parathion, gamma-BHC (Lindane), hexachlorobenzene, isophorone, 4-methylphenol, naphthalene, 2-nitrophenol, 4-nitrophenol, 4-nitroaniline, N-nitroso-di-N-propylamine, pentachlorophenol, prometon, prometryn, propazine, simazine, simetryn, terbutylazine, and 1,2,4-trichlorobenzene.

Polychlorinated biphenyls (PCBs)-Aroclor-1254 have been detected in surface water, sediments, and soils at RFP during preliminary investigations. Maximum values that were identified during preliminary investigation for the Aroclor-1254 are shown in Table 2-1.

2.2 ARAR IDENTIFICATION

To provide a basis for determination of preliminary contaminants of concern, ARARs were developed based on Section 121(d) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), which requires that fund-financed, enforcement, and federal facility remedial actions comply with applicable or relevant and appropriate federal laws or promulgated state laws, whichever are more stringent. A summary of possible or potential sitewide chemical-specific ARARs is presented in Appendix A in Table A-1, Groundwater Quality Standards, Table A-2, Federal Surface Water Quality Standards, Table A-3, Statewide and Basin Surface Water Quality Standards, and Table A-4, Stream Segment Surface Water Quality Standards. Values presented in Appendix A of this report were corrected and updated from Appendix A in the Final TSP to include chemicals suspected to be present at RFP and current (as of February 1, 1992) federal and state health and environmental statutes and regulations. These ARARs are considered preliminary and will be subject to change as new federal and

state standards are imposed, and as additional information from the baseline risk assessment and site characterization investigations for each OU become available for development of feasibility studies. The final ARARs determination for each OU will be completed as part of the record of the decision process conducted for that specific OU.

Possible or potential sitewide ARARs were selected from Appendix A for comparison to sitewide maximum and minimum analyte concentrations in Section 2.3. The ARARs selected for comparison include maximum contaminant level (MCL) for drinking water, federal Ambient Water Quality Criteria (AWQC), and Colorado statewide, basinwide and stream-segment standards for surface water, groundwater, and radionuclides. The EPA's Health Effects Assessment (HEA) criteria for the ingestion of carcinogens and systemic toxicants in soil and water (U.S. EPA 1989a) were also selected. To-be-considered (TBC) maximum contaminant level goals (MCLGs), not yet effective, were not selected as ARARs for use in the Final TSP and Annual Report.

As the Remedial Investigations for RFP proceed, additional information will become available through the risk assessment process which will allow a determination of acceptable contaminant concentrations to ensure protection of human health and the environment. Development of a preliminary list of possible or potential chemical-specific ARARs allows the establishment of a list of preliminary remediation goals in the Feasibility Study process. This is a tentative listing of contaminants and preliminary anticipated cleanup concentration or risk levels for each medium. Preliminary remediation goals will serve to focus the development of alternatives on remedial technologies that can achieve the remediation goals. As more information becomes available, chemical-specific ARARs may become more refined as constituents are added or deleted.

Possible and potential ARAR values from Appendix A were selected for comparison to maximum and minimum analyte levels in Table 2-1. A comparison of the ARAR values for surface water, groundwater, and soil is presented in Table 2-2 to show the revisions between Annual Report and Final TSP document (Table 4-2). A number of these changes were due to an expanded listing of chemical data available from the RFEDS database. Other changes were due to new state regulatory standards for groundwater and surface water. The process for selecting potential ARAR values was also modified slightly from that presented in the Final TSP. For the Annual Report, the most stringent federal or state standard (excluding MCLGs at zero) or HEA criterion was used as the principal ARAR for both surface water and groundwater. Maximum Contaminant Level TBCs (standards to become effective in 1992 or 1993) were included for consideration as potential ARARs. For those chemicals which had no federal or state standard, the lowest systemic or carcinogenic HEA criterion was used for surface water and groundwater. Where any of these standards were below the detection limit (minimum value in Table 2-1), the detection limit was listed as the potential ARAR. The decision was made for the Annual Report to include the state agricultural values for consideration in developing the possible and potential ARARs. The Final TSP did not consider the state agricultural values when developing the ARARs.

The potential soil ARARs/TBCs were based on the lowest HEA criterion (systemic or carcinogenic) with the detection limit used as the default value where the lowest HEA criterion was below the detection limit. This process is consistent with the methodology used in the Final TSP. The potential ARAR value for plutonium in soils or sediments was based on State of Colorado (1985) Rules and Regulations Pertaining to Radiation Control. The potential ARARs for gross alpha and gross beta emissions in soils and sediments were based on DOE and CDH requirements (U S DOE, February 1990 and CDH, December 1985).

2 3 SUMMARY OF CONTAMINANTS IN TWO OR MORE OUs AND COMPARISON TO ARARs

The following subsections review data screening conducted by media for the Annual Report. The results of the comparison to ARARs and identification of analytes which exceeded ARARs in two or more OUs are presented in Table 2-3.

2 3 1 Groundwater

Elevated levels (e.g., above ARARs) of inorganics, metals, volatile and semivolatile organics, and radionuclides have been detected at various individual hazardous substance sites (IHSS's) within a given OU. Those analytes which exceeded ARARs in two or more OUs have been considered in sitewide treatability studies.

As shown in Table 2-3, maximum values in groundwater exceeded ARARs in two or more OUs for the inorganic chemicals chloride, cyanide, nitrate, nitrate + nitrite, and sulfate. In addition, pH values and total dissolved solids (TDS) concentrations exceeded ARARs for groundwater. These were noted in the Final TSP and no additional analytes were identified for the Annual Report.

Metals exceeding ARARs, as noted in the Final TSP for groundwater in two or more OUs, included arsenic, cadmium, chromium, iron, lead, manganese, and selenium. Additional analytes identified for the Annual Report include aluminum, cobalt, copper, mercury, nickel, vanadium, and zinc.

Maximum values in groundwater exceeding ARARs in two or more OUs, as reported in the Final TSP, include 1,1-dichloroethene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, carbon tetrachloride, methylene chloride, tetrachloroethene, trichloroethene, and vinyl chloride. Additional volatile organics identified for the Annual Report include 1,2-dichloroethane, 1,2-dichloroethene, 1,2-dichloropropane, benzene, and chloroform.

Semivolatile organics in groundwater were not identified in the Final TSP in two or more OUs. Based on the review of the database output, bis(2-ethylhexyl)phthalate and N-nitrosodiphenylamine were identified above groundwater ARARs for the Annual Report.

Radionuclides exceeding ARARs in two or more OUs for groundwater for the Final TSP include gross alpha activity. Additional radionuclides exceeding ARARs for the Annual Report include gross beta activity, radium (Ra) 226, Ra 228, strontium 90, tritium, and uranium (U) total.

2 3 2 Surface Water

As reported in the Final TSP, maximum values in surface water exceeding ARARs in two or more OUs for the inorganic chemicals include chloride, nitrate, nitrate + nitrite, and sulfate. Values of pH both higher and lower than ARARs were recorded for surface water, and total dissolved solids (TDS) concentrations also exceeded ARARs in surface water in the Final TSP. Cyanides were the only additional analyte or parameter identified for the Annual Report.

Metals exceeding ARARs, as noted in the Final TSP for surface water in two or more OUs, include aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, iron, lead, and manganese. Additional metal analytes were identified for the Annual Report and include copper, mercury, nickel, selenium, silver, thallium, and zinc.

Volatile compounds exceeding ARARs in two or more OUs as reported in the Final TSP include 1,1-dichloroethene, carbon tetrachloride, methylene chloride, tetrachloroethene, and trichloroethene. Additional analytes were identified for the Annual Report and include 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, 1,2-dichloroethene (total), chloroform, and vinyl chloride.

For the Annual Report, semivolatile compounds exceeding ARARs in surface water in two or more OUs include alpha-chlordane, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, naphthalene, N-nitrosodiphenylamine, and phenol. Based on preliminary investigation results, PCBs were reported at concentrations above ARARs in surface water for more than two OUs.

The radionuclides identified in the Final TSP as exceeding ARARs include gross alpha and gross beta activity and plutonium (Pu) 239+240, radium (Ra) 226, tritium and uranium (total) in two OUs. Additional radionuclides were identified for the Annual Report and include americium (Am) 241, and Ra 228.

2 3 3 Soils and Sediments

Few chemicals were reported in the Final TSP as exceeding ARARs in soils or sediments. This is due to the soil and sediments database being more limited than the database for groundwater and surface water. Also, few ARARs are available for soils and sediments, and numerical values of ARARs which do exist are relatively high. The only chemicals reported in the Final TSP at concentrations exceeding ARARs were the metal beryllium in soils and sediments and the radionuclides gross alpha activity in soils and sediments, and Pu 239+240 in soils and sediments. For the Annual Report, PCB Arochlor-1254,

based on preliminary investigation results, was the only additional analyte reported in concentrations above ARARs in soils

2.4 LITERATURE SEARCH

A literature search of published materials was conducted to obtain and review new information on treatment technologies. The following computer databases were researched using Dialog as a gateway:

- Enviroline
- Pollution Abstracts
- Environmental Bibliography
- Compendex
- National Technical Information Service (NTIS)

Initially, a list of titles was generated based on the search using key words and subjects. This material was reviewed and abstracts were requested for articles and papers identified as appropriate. A review of journal articles, conference proceedings, and federal publications was also conducted to complement the database searches. This literature search was used to supplement the previous information compiled for the Final TSP. This included references developed for application to Superfund sites, Resource Conservation and Recovery Act (RCRA) Best Demonstrated Available Technology (BDAT) studies, standard engineering textbooks, DOE studies, and other project experience. The following technology databases were accessed:

- Alternative Treatment Technology Information Center (ATTIC), U.S. EPA
- Technology Data Base DOE Research and Waste Management, Oak Ridge, Tennessee
- Remedial Technology Information System (RTIS), DOE Idaho National Engineering Laboratory, Idaho Falls, Idaho
- National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia
- Rocky Mountain Arsenal Technology Data Base, U.S. Army Program Manager's Office, Commerce City, Colorado
- Office of Solid Waste and Emergency Response (OSWER) Bulletin Board System, U.S. EPA Technology Innovation Office, Washington, D.C.
- Water Engineering Research Laboratory (WERL), Treatability Data Base System, Risk Reduction Engineering Laboratory, U.S. EPA, Cincinnati, Ohio

New references reviewed and used in this report are presented in Section 5.0 and in the appendices for each technology data summary.

TREATABILITY STUDY PROJECTS

This section summarizes treatability studies interim reports and results from other RFP research studies generated since the Final TSP. This information was considered in the review of the treatability technology selection for the Annual Report. The status of the projects and plans for Fiscal Year 1992 are also discussed.

One research report has been issued and addresses the bench-scale testing of physical size separation for treatment of radionuclide-contaminated soils at OU2. New and additional information on the Colloid Polishing Filter Method (formerly Techtran) process for treatment of radionuclides in water were reported. Bench-scale tests were conducted using RFP groundwater.

Bench-scale tests of granular activated carbon (GAC) treatment of water contaminated with volatile organic compounds (VOCs) have been conducted on surface waters from OU2. Bench-scale tests for removing suspended solids by coagulation, precipitation, and filtration were also conducted. Bench-scale tests of the use of ultraviolet (UV) hydrogen peroxide oxidation treatment of OU1 groundwater contaminated with VOCs were conducted.

Pilot-scale tests were performed as part of the OU2 surface water IM/IRA and are planned for the OU2 subsurface IM/IRA. The screening process for bench and pilot-scale studies is described in Section 4.0.

3.1 BENCH-SCALE TESTING**3.1.1 OU1 Groundwater IM/IRA Tests**

Bench-scale tests were conducted for treatment of OU1 groundwater contaminated with VOCs using UV/hydrogen peroxide oxidation treatment. In September 1991, bench-scale testing was performed to further evaluate the oxidation of chlorinated solvents in groundwater using ultraviolet light and hydrogen peroxide. The purpose of this investigation was to determine operating and design parameters prior to the startup of the OU1 Interim Measure/Interim Remedial Action (IM/IRA) full-scale unit in 1992.

A single composite sample was prepared from groundwater taken from five representative wells in OU1 and sent to Peroxidation Systems, Inc. (PSI), in Tucson, Arizona. PSI performed four optimization tests to determine the best operating conditions prior to running a confirmation test.

Based on preliminary results, the tests demonstrated that concentrations of volatiles in effluent water were reduced to acceptable levels. Analysis of off-gas samples taken during testing yielded values as high as 3100 ppb 1,1,1-trichloroethane. It appears that a significant level of reduction occurred due to

stripping caused by the evolution of gas bubbles. At this time, an evaluation has not been completed to establish if similar stripping occurs in full-size equipment. Test results showed that destruction/removal efficiencies were greater with a hydrogen peroxide concentration of 50 ppm as opposed to 100 ppm, and a pH of 5 as opposed to an unadjusted pH of 7.5. The test indicated improved performance after pretreatment consisting of the addition of a flocculent (alum) combined with filtration. The results of this bench-scale test will be used as a basis for the system operation scheduled for early 1992.

3.1.2 OU2 Surface Water IM/IRA Tests

Bench-scale tests were conducted on samples of OU2 surface water contaminated with VOCs using several types of GAC in a column configuration. Analyses of the water sample prior to treatment indicated that the following VOCs were present: 1,2-dichloroethane [97 micrograms per liter ($\mu\text{g/l}$)], chloroform (33 $\mu\text{g/l}$), 1,1,1-trichloroethane (13 $\mu\text{g/l}$), carbon tetrachloride (140 $\mu\text{g/l}$), trichloroethene (97 $\mu\text{g/l}$), and 1,1,2,2-tetrachloroethane (52 $\mu\text{g/l}$). Preliminary results indicate that VOCs can be removed to below detection limits for all experimental conditions tested. No differences were indicated among the various types of GAC tested.

Bench-scale treatability tests were also performed to evaluate coagulation/precipitation/filtration technologies for removal of suspended solids. Jar settling tests and a combination of jar settling followed by sand column filtration tests were conducted. Several different coagulants were tested at various dosage rates and pH levels. Preliminary results show that direct filtration without using coagulants may be feasible. Provisions for chemical addition and precipitation may be required for full-scale treatment. These operations would be used periodically when influent suspended solids levels are elevated.

In addition to the tests described above, the OU2 Treatability Study Program planned to conduct bench-scale testing for removal of radionuclides and metals from surface water using GAC, ion exchange, chemical precipitation, and adsorption on selected adsorbents. These tests were not performed because OU2 surface water did not contain sufficient concentrations of radionuclides for bench-scale testing.

3.1.3 Physical Separation

The removal of actinides from soils at OU2 was bench tested in 1989, and the results are presented in Research Report RFP-4479 dated September 12, 1991. Removal of actinide-contaminated fine clay particles from soils was tested using a gravimetric separator (mineral jig) in conjunction with wet sieving. In addition, dry sieving, attrition scrubbing, and rotary scrubbing were evaluated.

Wet sieving removed more than 98 percent of the radionuclide activity from coarse gravel to coarse sands, less than 50.0 to 4.0-mm, based on the Unified Soil Classification System (USCS) grain-size scale. When the soil was first size-separated and then wet sieved, more than 99 percent of the activity was removed. The decontaminated soils fraction of less than 50.0 to 4.0-mm represented greater than 50 weight percent of the untreated soils in each test.

Actinide removal from coarse to medium sands, less than 4.0- to 2.4-mm, and fine sands, less than 2.4- to 0.42-mm, followed a selected sequence. Attrition scrubbing removed more contamination than wet sieving which removed more contamination than rotary scrubbing. Attrition scrubbing was found to enhance the actinide removal prior to wet sieving of coarse to medium sands and fine sands by 10 percent and 20 percent, respectively. The mineral jig removed actinide-containing clays from the <0.42-mm fractions. The americium was lowered from 100 to 11 pCi/g in 4 weight percent of the soil (<0.42 to 0.25 mm).

The tests discussed above were the results of bench testing of gravimetric physical separation (TRU Clean™) and other size separation techniques for the removal of radionuclide contamination from RFP soils. These were research tests conducted using wind-blown soils obtained from the southeast corner of the 903 Pad. The test showed that significant decontamination of coarse particle size ranges could be achieved. The tests did not evaluate soil washing to remove radionuclides from the soil particles. Additional tests using different types of soil from other areas of contamination at RFP would be useful. The report did not present any conclusions regarding whether the available data were sufficient to establish that physical separation techniques should be implemented for cleanup of radionuclide contaminated soils at RFP.

These preliminary results suggest that particle size separation warrants further consideration for treatment of soils contaminated with radionuclides. Additional testing will be required to determine if this technology is applicable for implementation at RFP. Soil washing and gravimetric physical separation (TRU Clean™) were selected for inclusion in the sitewide Treatability Test Program in the Final TSP.

3.1.4 Colloid Polishing Filter Method

Bench-scale tests were conducted for the Techtran process (now known as the Colloid Polishing Filter Method). This technology has been selected for demonstration at RFP as part of the EPA Superfund Innovative Technology Evaluation (SITE) program. The contaminated groundwater was passed through filter beds composed of Filter-Flow-1000 material with and without chemical pretreatment. The work was carried out with RFP groundwater recovered from the OU4 interceptor pump house (ITPH) #95, using radioactive tracers (Pu 239, Am 241 and Ra 226). The ITPH #95 water, mostly bicarbonate (pH 7.6), contained approximately 31 picocuries per liter (pCi/l) of U 238. The purpose of these experiments was

to evaluate the feasibility of the technology and to establish an optimum condition for maximum retention of radionuclides such as U, Pu 239, and Am 241

Eight different experimental conditions were tested including various values of pH adjustment and additions of sodium sulfide and/or sodium bisulfite. The purpose of sodium bisulfite was to reduce U+6 to the U+4 state and Pu+4 to the Pu+3 state. The sodium sulfide addition was added to generate insoluble metal sulfides and allow them to precipitate.

The influent or intermediate effluent and final effluent were analyzed for various major and trace elements with special emphasis on U, Pu 239, and Am 241 radionuclides. Based on the radionuclide results, all eight experimental conditions appear favorable for a future demonstration. The retention factors for U, Pu 239, and Am 241 range from 200 to 1000 (which equals approximately 95.5 to 99.9 % removal). Since the effluent values are below or at the detection limits (0.05 pCi/l), the true retention factors may be higher. It has not yet been determined which process conditions are most favorable for retention. Additional bench tests are in progress. A decision will be made based on these tests prior to the OU4 field demonstration planned for 1992.

3.2 PILOT-SCALE TESTING

A pilot test of the use of GAC treatment of OU2 surface water contaminated with VOCs is in progress. This program is to be expanded to include microfiltration for the removal of heavy metals and radionuclides. A test of the pilot groundwater extraction and treatment system at OU1 is planned for March 1992.

3.2.1 OU1 IM/IRA Systems Operation Test

The OU1 IM/IRA Systems Operation (SO) Test on the Total System is an IAG scheduled evaluation of the overall performance of the groundwater recovery and treatment system. The testing is scheduled to take place in spring 1992. The test objectives are to ensure proper operation of each component, evaluate the performance of the system, determine operating parameters, and identify potential problems in future operations.

The test includes hydrostatic testing, which was initiated in summer 1991, of lines and process equipment, instrument calibration, and testing of the groundwater recovery system. However, a major portion of the test will be committed to the evaluation of the UV/hydrogen peroxide treatment system and the ion exchange system. The OU1 IM/IRA bench-scale test on UV/hydrogen peroxide treatment was used as a precursor to the SO test. This test indicated the need for evaluating precipitation, VOC emissions, and adsorption of the UV light by suspended solids, as well as overall removal efficiency for VOCs. Testing of the ion exchange system will include testing the regeneration system, evaluating

removal efficiencies, and adjusting the operating parameters of the system to achieve improved performance

Upon completion of the testing, and after analytical results are received, an SO test report will be prepared. The SO test report will detail the tests performed and the results of those tests, as well as make conclusions and recommendations about the groundwater recovery/treatment system.

3.2.2 OU2 Surface Water IM/IRA Pilot Tests

A pilot GAC treatment system for treatment of surface water in OU2 began operation in spring 1991 and is scheduled to continue operation until summer 1992. The system was designed to treat 1,1-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethane, chloroform, carbon tetrachloride, trichloroethene, and tetrachloroethene. The system has been effective in treating VOCs. However, only 1,2-dichloroethene, carbon tetrachloride, trichloroethene, and tetrachloroethene have been identified above detection limits in the surface water collected for testing. The system design capacity was 60 gallons per minute (gpm), while the average flow rate treated to date has been 14 gpm. No major problems have been encountered. A draft report on the pilot treatability study is due to the agencies in spring 1992.

A pilot test of a radionuclide removal system is planned as Phase II of this test program. This will involve the addition of a microfiltration system for the removal of radionuclides and heavy metals to the existing GAC process. The microfiltration system is expected to begin operation in the spring of 1992 and operation is planned to continue through summer 1993.

3.3 TREATABILITY STUDY WORK PLANS

Pilot-scale treatability testing to address the residual free-phase VOCs for OU2 and the radionuclide contamination beneath 903 pad for OU2 will be evaluated and coordinated through the Subsurface Interim Measure/Interim Remedial Action Plan (IM/IRAP). In situ vacuum-enhanced vapor extraction has been identified for implementation of a pilot test in the Subsurface IM/IRA. In situ steam stripping is being considered for pilot testing in the IM/IRA and potentially has the capability to recover VOCs and radionuclides. This technology is presently being tested at Lawrence Livermore National Laboratory in Livermore, California. Bench-scale treatability testing of dehalogenation and chemical oxidation will be conducted in the future to determine if these remedial technologies are applicable for the OU2 site and warrant pilot-scale testing. The Subsurface IM/IRAP will be released for public comment in 1992.

Two physical separation treatability study work plans (TRU Clean™ and Magnetic Separation) for the treatment of radionuclide-contaminated soil will be submitted to the EPA and CDH for their review in November 1991. A work plan for soil washing of plutonium will be developed and soil washing experiments will be performed in 1992.

The work plan for Treatability Studies of Different Types of Oxidation/Reduction Processes will be completed and submitted to EPA and CDH for review early in 1992. Bench-scale tests are planned in 1992. A work plan for the Ultrafiltration/Microfiltration Treatability Study is presently under development and will be submitted to the EPA and CDH in early 1992. Bench-scale tests are planned in 1992. A work plan for testing potassium ferrate precipitation (TRU-Clear™) for removal of radionuclides, metals, and organics from water will be prepared in Fiscal Year 1992.

A feasibility study will be conducted for OU1 in fiscal year 1992. The feasibility study process may include additional treatability studies for soil/sediments and groundwater/surface water.

3.4 REMEDIATION TECHNOLOGIES

As part of the overall treatability study program outlined in the IAG, DOE has initiated a comprehensive investigation of methods potentially available for use in corrective/remedial action. These studies are consistent with section XI of the IAG and will cover the range of alternatives required for the analysis of remedial alternatives during both IRA planning and Corrective Measures/Feasibility Studies (CM/FS). Under this program, studies will be conducted to provide sufficient data to allow remedial alternatives to be fully developed and evaluated during feasibility studies, to support the remedial design of selected alternatives, and to reduce cost and performance uncertainties for remedial alternatives. Sitewide treatability studies are being performed to expedite the screening of treatment technologies and alternatives. In the same manner, this program will expedite the remediation process by evaluating and testing existing and innovative technologies that enhance site characterization and assessment, subsurface contaminant collection and recovery, and in situ remediation. Projects are in progress or will be developed with DOE's Office of Technology Development, EPA's Office of Research and Development, the U.S. Geological Survey, and various universities. Potential activities include the evaluation, development, testing, and demonstration of procedures and technologies in the following categories:

- Environmental Characterization and Assessment (eg., geophysical techniques, drilling technologies, downhole chemical sensors, in situ radiometric detectors, hydrologic testing, monitoring system design, data mapping and display, contaminant fate and transport, two-phase flow systems, hydrologic and geochemical modeling, statistical and geostatistical analysis)
- In situ Remediation (eg., groundwater contaminant recovery systems, soil vapor extraction, steam stripping, dehalogenation, chemical oxidation, bioremediation)

In Fiscal Year 1992, RFP will plan, organize, and implement a program of applied environmental research, technology evaluation and testing in the areas of site characterization, assessment and in situ remediation that focuses specifically on technical RFP environmental restoration issues.

3 5 RELATED TECHNOLOGY DEVELOPMENT PROGRAMS

3 5 1 Radionuclide Control Plan

A work plan titled Final Work Plan for the Control of Radionuclide Levels in Water Discharges from RFP will be issued in January 1992 as part of the Inter-Agency Agreement. This work plan requires identification of potential improvements in treatment to be used in the event that water quality for the terminal ponds exceeds Colorado standards. The work plan includes proposals in four areas: (1) improving present treatment, (2) characterizing the physicochemical nature of radiochemical contaminants, (3) tracking potentially applicable treatment methods developed by others, and (4) considering additional bench-scale treatability tests.

RFP currently provides treatment to remove certain waterborne contaminants from RFP pond water prior to discharge. Treatment includes particulate filtration and GAC. Analysis of available data indicates that current operation is minimally effective at removing radiochemical contaminants, which are thought to be associated with colloids/particulates in the micron to sub-micron size range. Improvements to the current treatment approach will be pursued in the future. General facility improvements are being implemented including consolidating operations into a weather-proofed facility and providing piped conveyances for Pond B-5 and Pond C-2 water to the Pond A-4 Treatment Facility. Treatment process enhancements to be evaluated include installation of improved bag/cartridge filters and multimedia sand filters. Bag/cartridge filter improvement evaluation will involve testing of various filter bags and cartridges to determine particulate removal efficiencies. A pilot testing program will be initiated to evaluate multimedia sand filtration as the first or second unit operation in the treatment process. Particle counting technologies are being used to directly measure filtration effectiveness and produce specific particle distributions for unit (treatment) operations which can remove micron-sized particles.

The characterization of radionuclide contaminants will include chemical characterization and speciation and identification of sources and potential source control measures. The characterization will identify factors important to changes in solubility, complexation, and adsorption of radiochemical contaminants. This information will assist in developing and implementing specific treatment approaches for removal of low-level radiochemical contaminants from pond water. The study will also identify sources and transport mechanisms that result in radiological contaminants in RFP pond water. This effort will be accompanied by identification and testing of appropriate control technology to eliminate exceedances of Colorado standards.

The work plan includes provision for evaluating potentially applicable technologies and conducting bench-scale treatability testing, as appropriate. This will include monitoring the technology review process and treatability test programs conducted as part of the sitewide Treatability Studies Program. Technology evaluations and testing conducted at individual OUs will also be monitored. The work plan

proposes conducting annual reviews of these potentially applicable technologies which will be incorporated and addressed in future annual reports

3 5 2 Comprehensive Treatment and Management Plan

The Land Disposal Requirements (LDR) requires hazardous waste to be treated to meet the best demonstrated available technology (BDAT) prior to being placed in a landfill. EPA has identified BDAT as either specific technologies (e.g., incineration) or as specified numerical standards. In addition, in order to discourage generators from attempting to avoid the disposal standards simply by storing the waste forever, the LDR regulations prohibit indefinite storage of hazardous and mixed wastes. In order to comply with these LDR provisions, the RFP Federal Facility Compliance Agreement (FFCA) was implemented. Implementation of the requirements of the FFCA allows for continued operation (i.e., generation and storage of mixed waste) while providing time for DOE to develop the technologies required to come into full compliance with the LDR regulations.

The Comprehensive Treatment and Management Plan (CTMP) is the foundation on which ultimate compliance with LDR is based. This plan will describe why treatment technologies are needed, how specific technologies were selected, and the applicability of technologies to the LDR problem at RFP. Schedules and milestones for developing and implementing the chosen technologies will be identified. The Annual LDR Progress Report is a requirement and will provide an update and status on the scope and magnitude of LDR mixed-waste issues at RFP including quantities in storage, storage locations, progress in LDR determinations and characterization efforts, and treatment technology implementation. Ultimate compliance can not be achieved until such time that LDR wastes can be treated and disposed of in the proper manner. As a result, the majority of activities involved in this project are centered around the development and implementation of treatment technologies for hazardous and radioactive waste. The IAG treatability studies program is focused on treatment of soil and water contaminated with much lower levels of hazardous constituents than LDR wastes.

3 5 3 Technology Investment Strategy

To help focus resources on the projects that have the greatest potential, RFP is working toward a Technology Investment Strategy (TIS). This strategy is the management plan for technology development activities, priorities and resources. A systems analysis approach is being developed to determine which projects to pursue, which projects to abandon, and what criteria to use in making those choices. Projects will be ranked in order of importance and solutions developed utilizing formalized decision analysis techniques. Solutions identified for consideration can include administrative changes, implementing waste minimization technologies, implementing waste treatment technologies, or developing additional characterization or analysis capabilities. The systems analysis methodology will provide the basis for selecting technologies for the CTMP. The strategy will seek to leverage RFP efforts.

with technical research and development efforts at other DOE laboratories, universities, and, when applicable, private-sector companies

SCREENING AND SELECTION OF TECHNOLOGIES

This Annual Report has been designed to review, reevaluate and rescreen technologies identified in the Final TSP for inclusion in the Treatability Studies Program based on new site characterization data, ARARs, and the literature search. The Annual Report also evaluates and screens new technologies identified or additional information obtained on existing and innovative technologies.

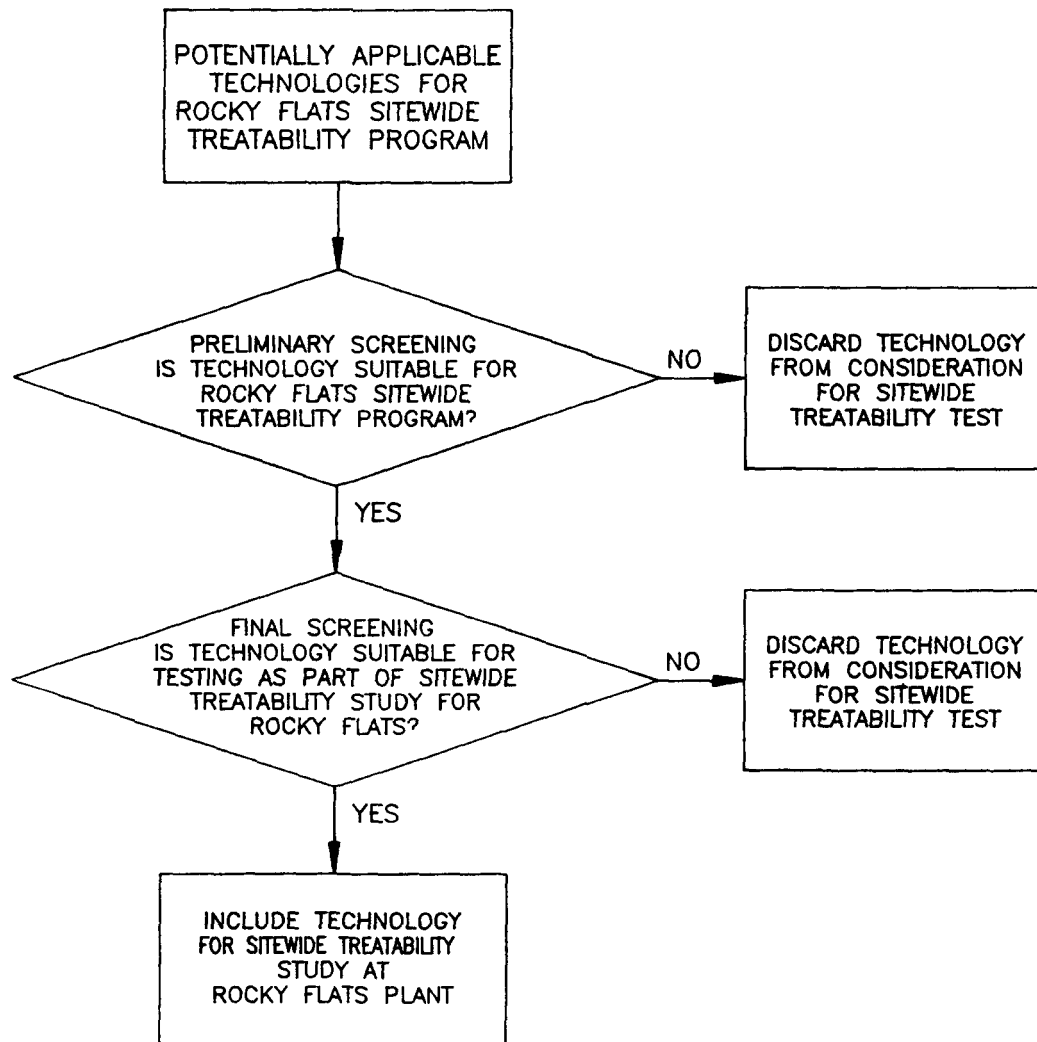
The methodology for technology selection employed for the Annual Report is the same as that applied in the Final TSP. This section briefly summarizes that methodology and presents the results of the updated technology screening for the Treatability Studies Program.

4.1 TECHNOLOGY SELECTION PROCESS

The site characterization data were reviewed and compared to available ARARs to identify major contaminant types and associated media that exist at RFP. A literature/database search was conducted to identify new information on technologies potentially applicable to the contaminant types and media identified in two or more OUs at RFP. These technologies were then subjected to a two-step screening process. The preliminary screening identified those technologies suitable for application at RFP. The final screening identified which of these technologies to include in the sitewide Treatability Studies Program. The two-step screening method is illustrated in Figure 4-1. Statements of Work (SOWs) were prepared for new technologies selected for treatability testing.

4.1.1 Review of Site Characterization Data and ARARs

The site characterization data and ARARs were updated as previously described in Sections 2.1 and 2.2. Information on ARARs was updated as described in Section 2.2. The updated site characterization data were compared in Section 2.3 to identify those contaminants which were found to exceed ARARs in two or more operable units at RFP. The contaminants identified were grouped in categories of contaminant type (e.g., volatile organics) and media (e.g., groundwater).



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SPECIFIC SELECTION PROCESS AS
APPLIED TO TECHNOLOGIES TO BE
INCLUDED IN ROCKY FLATS SITEWIDE
TREATABILITY TEST PROGRAM

4.1.2 Review of Technology Data

The review of technology data included a status review of ongoing treatability test programs at RFP and a review of new information on potentially applicable technologies. The status of treatability tests in progress at RFP was summarized in Section 3.0. Sources of information that were used include literature/database searches, review of conference proceedings, EPA guidance documents, government reports, and vendor information. The review included technologies applicable to newly identified contaminant categories, newly identified technologies, and new information on previously screened technologies.

4.1.3 Preliminary Screening Process

The preliminary screening of treatment technologies consisted of identifying and associating the applicable technologies with the major contaminant categories, and screening to select technologies suitable for application at RFP. The following criteria were applied in identification of technologies for screening:

- Potential applicability to new major contaminant categories that were identified
- New technologies identified with potential applicability to any major contaminant category
- Innovative technologies for which new information relevant to the selection process was obtained from other RFP testing programs or from literature
- Applicability to contaminant categories in two or more OUs

The criteria for technologies applicable to two or more OUs were previously applied during the final screening in the Final TSP.

New technologies identified and technologies applicable to newly identified contaminant categories were included in the preliminary screening process. Technologies previously screened in the Final TSP, for which additional information was available, were also included. Technology data summaries were prepared for each technology included in the screening process. These data summaries are presented in Appendix B for groundwater/surface water treatment technologies and in Appendix C for soil/sediment treatment technologies.

The preliminary screening process is illustrated in Figure 4-2. Criteria for the preliminary screening include the following:

- Applicability
- Removal efficiency
- Potential to meet cleanup goal

- Technology maturity
- O&M requirements
- Implementability
- Adverse impacts

The decision to retain a technology for evaluation of treatability testing was an engineering judgment based on the information available from the literature search and other sources

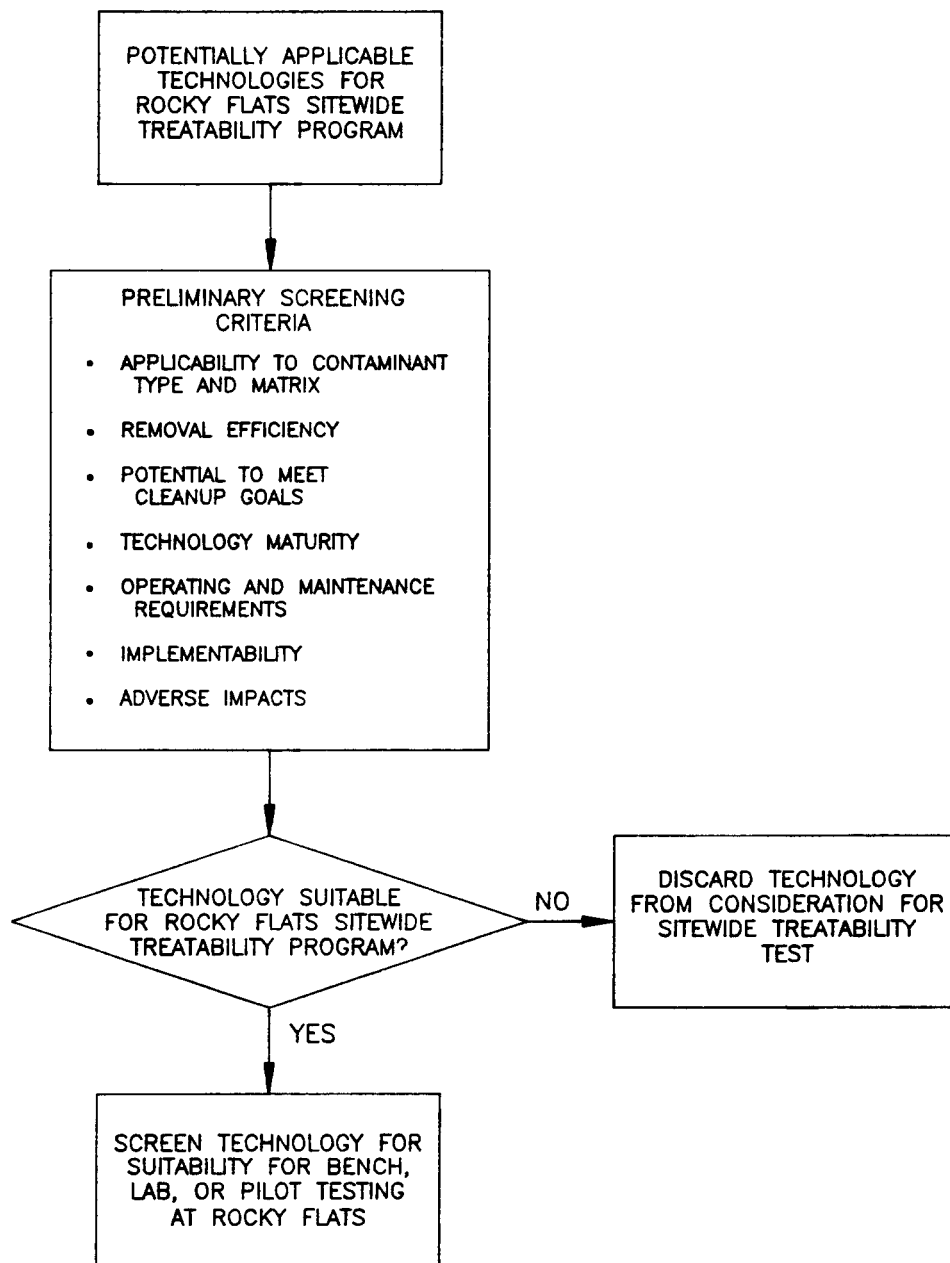
4 1 4 Final Screening Process

The final screening process selected those technologies suitable for inclusion in the sitewide Treatability Study Program and is illustrated in Figure 4-3. An evaluation was made if additional information from treatability testing was needed for selection of the technology for application at RFP. If additional information was not required, the technology was not considered for testing.

The technology was then compared to other proven technologies. If the technology offered no significant advantages in terms of effectiveness, cost, O&M requirements, or reduction in adverse impacts, it was eliminated from further consideration for testing. Those technologies retained after evaluation according to these criteria were included in the treatability program if the technology could be tested at the laboratory or bench scale. A preliminary assessment was made of the anticipated EPA, state, and community acceptance of pilot testing of those technologies which would require treatability testing at this scale. Technologies were not selected or rejected for pilot testing based on this preliminary assessment on acceptance by the EPA, state, and community.

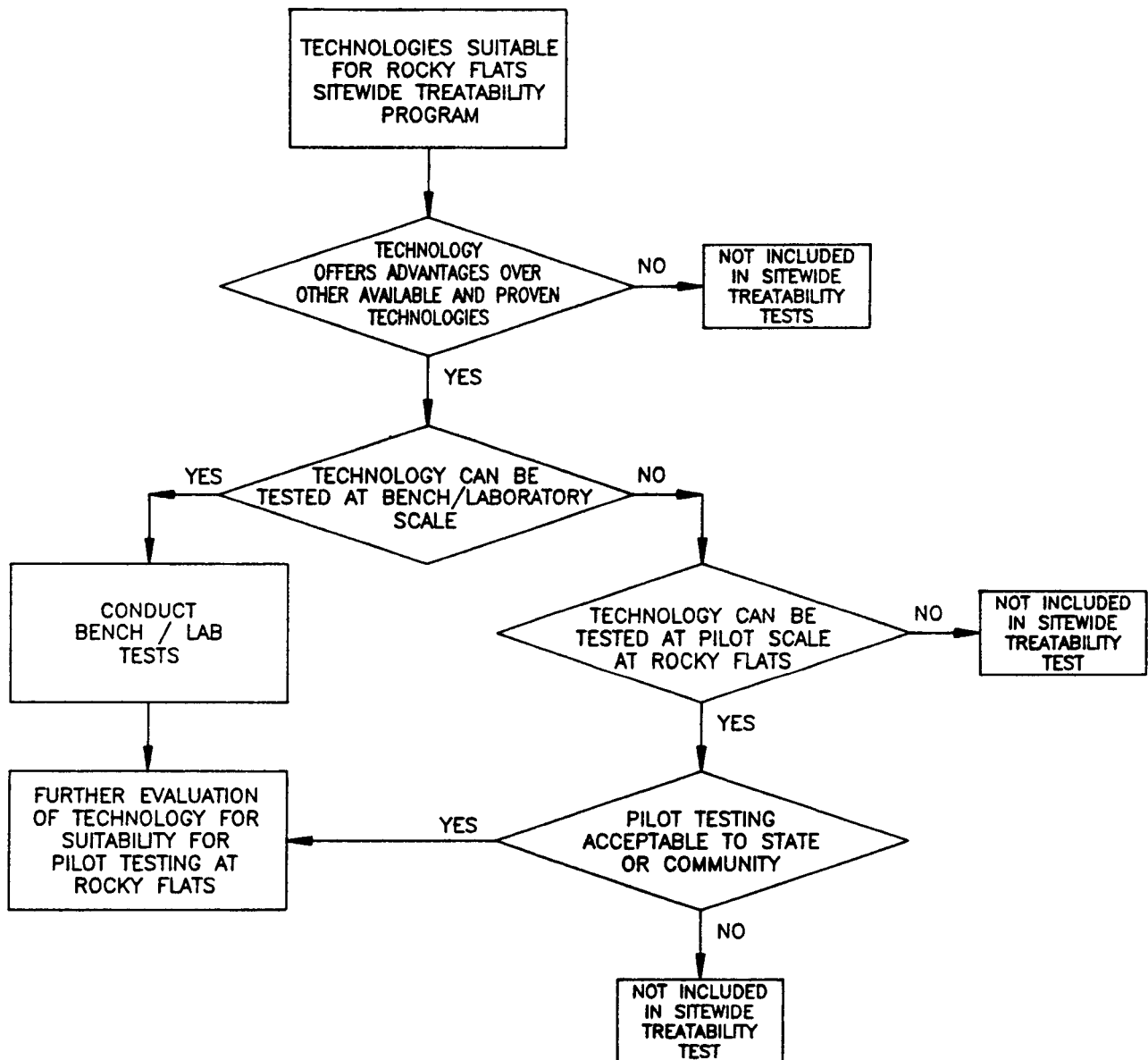
The final screening process for the Annual Report is intended to review and update the technology selection completed in the Final TSP. The final screening process includes those technologies retained following the preliminary screening process and those technologies previously considered in the final screening process in the Final TSP, for which new information is available having substantial impact on the screening process. The final screening also included technologies which were retained in the Final TSP after preliminary screening and not subjected to final screening because no analytes were identified that exceeded ARARs in two or more OUs in the Final TSP. These technologies were subjected to a final screening based on the updated review of ARARs and contamination data in this Annual Report.

Statements of Work (SOWs) were prepared for new technologies selected for the sitewide Treatability Studies Program for the Annual Report. These SOWs are included in Appendix D of this report and supplement SOWs prepared for the Final TSP. An order of magnitude cost estimate was prepared for pilot testing of identified technologies to serve as an input into decisions regarding priority and scheduling of tests.



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PRELIMINARY SCREENING OF
TECHNOLOGIES FOR SUITABILITY
FOR ROCKY FLATS SITEWIDE
TREATABILITY PROGRAM



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FINAL SCREENING OF
TECHNOLOGIES FOR TREATABILITY
TESTING AT
ROCKY FLATS

4 1 5 Pilot Testing Evaluation

The process for evaluating the suitability of technologies for pilot testing is presented in Figure 4-4. This procedure, adapted from the EPA guidance document for conducting treatability studies, was designed to allow the continuous evaluation of new information for each technology based on bench-scale testing and a literature search through the life of the treatability program. The technologies selected for pilot testing in the Final TSP and the Annual Report will be reevaluated annually. The review will include additional information on ARARs, permits, cleanup levels, agency approval, and environmental risks of pilot testing. Relative costs for implementing a program for pilot and full-scale testing will be prepared, as appropriate.

4 2 TECHNOLOGIES EVALUATION AND SELECTION SUMMARY

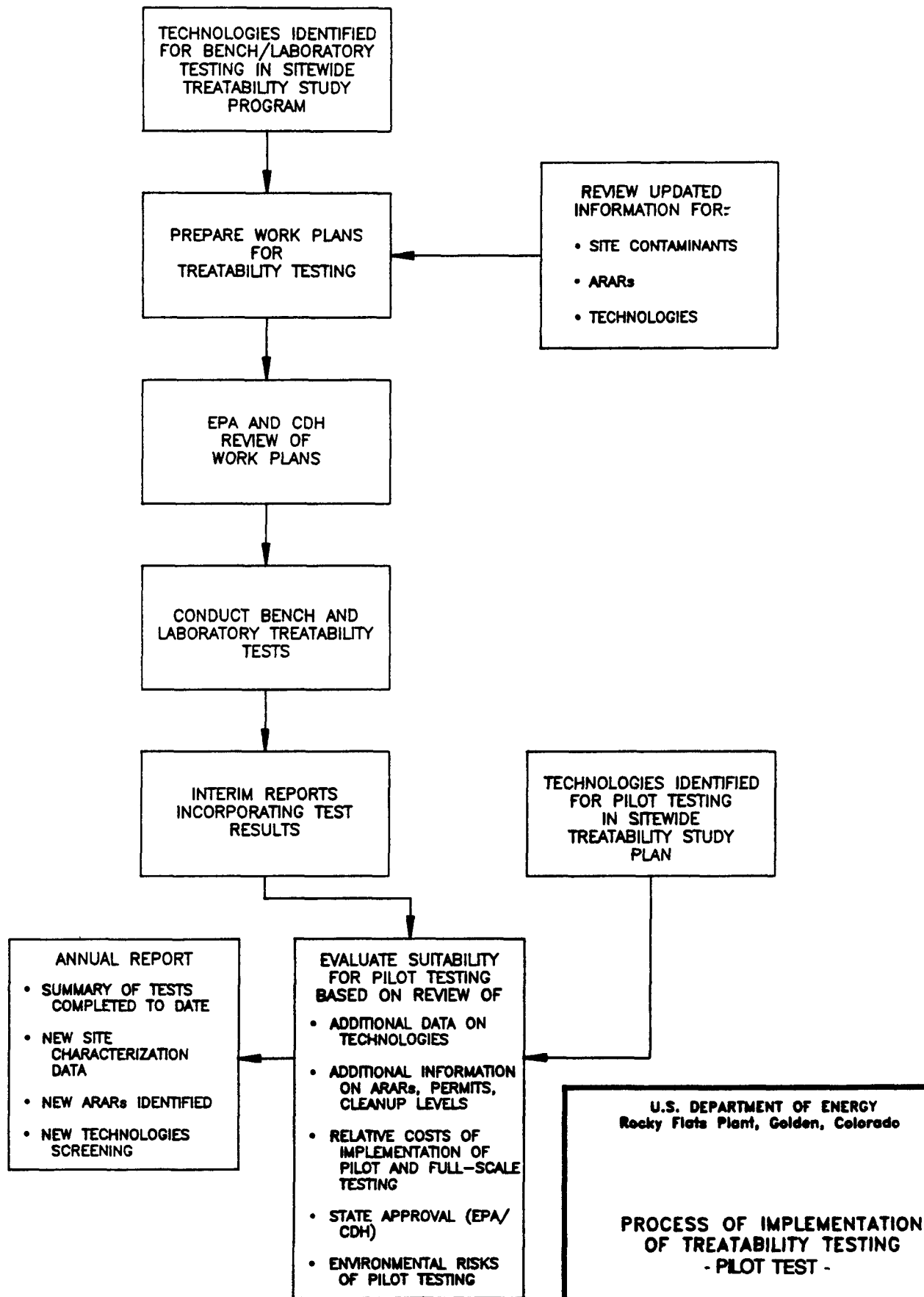
This section presents the results of the technology selection process for technologies that are appropriate for inclusion in the sitewide Treatability Studies Program. The technologies which were preliminarily screened are presented in Section 4 2 1. The final technology screening process results are presented in Section 4 2 2.

A technology data summary was prepared for each treatment technology subjected to screening. The data summaries for groundwater/surface water treatment technologies are included in Appendix B, while those for soil/sediment treatment technologies are included in Appendix C. Statements of Work were prepared for each technology selected for testing and are presented in Appendix D 6.

4 2 1 Preliminary Screening

The technologies applicable to groundwater or surface water matrices identified for preliminary screening are listed in Table 4-1A. This table includes technologies applicable to these contaminant groups: volatile organics, semivolatile organics, PCBs, inorganics, metals, and radionuclides. Some new technologies identified for the preliminary screening are not innovative or emerging technologies but were not previously identified in the literature search for the Final TSP. The technologies applicable to soil or sediment matrices which were identified for preliminary screening are listed in Table 4-1B. This table includes technologies applicable to the contaminant groups PCBs, metals, and radionuclides. Two or more OUs were identified to have contaminant concentrations which exceeded ARARs for each of these contaminant groups, as presented in Table 2-2. The contaminant group PCBs was previously discussed in the Final TSP, but no technologies were screened prior to the Annual Report.

The preliminary screening for groundwater/surface water technologies is presented in Table 4-2A and that for soil/sediment technologies is presented in Table 4-2B. The technologies retained for final screening are presented in Table 4-3A for groundwater/surface water, and Table 4-3B for soil/sediments.



The groundwater/surface water technologies included for final screening for the contaminant group semivolatiles includes technologies which were retained following preliminary screening in the Final TSP. These technologies were not subjected to final screening in the Final TSP since, at that time, semivolatile contaminants were not identified in two or more OUs. The rationale for rejection of those technologies not retained is presented in Table 4-4A for groundwater/surface water, and Table 4-4B for soil/sediments.

4.2.2 Final Screening

The final screening process for groundwater/surface water technologies is presented in Table 4-5A, and for soil/sediment treatment technologies in Table 4-5B. The final screening process in these tables includes some technologies which were previously subjected to final screening in the Final TSP for which new information warranted a new review.

The groundwater/surface water treatment technologies identified for laboratory or bench-scale testing in the final screening process are presented in Table 4-6A. Adsorption, ion exchange, oxidation/reduction, ultrafiltration/microfiltration, and potassium ferrate precipitation (TRU-Clear™) were all previously selected in the Final TSP. Potassium ferrate precipitation is to be tested for the removal of radionuclides and metals and potentially, organics. The other technologies are to be tested on both metals and radionuclides. Oxidation technologies such as ozonation, peroxide oxidation, UV oxidation, and UV photolysis technologies were identified for testing with application to PCBs. SOWs are included in Appendix D.

The soil/sediment treatment technologies identified for laboratory or bench-scale testing in the final screening process are presented in Table 4-6B. Magnetic separation, gravimetric physical separation (TRU Clean™), chemical soil washing, and the solidification/stabilization technologies (polymerization-epoxy, polymerization-polyester, portland cement, and masonry cement) were all previously identified for testing in the Final TSP. Magnetic separation and gravimetric physical separation (TRU Clean™) were identified for testing with application to radionuclides. The rest of the technologies are applicable to testing for radionuclides and metals.

The Final TSP selected oxidation technologies such as ozonation, peroxide oxidation, UV oxidation, and UV photolysis for pilot-scale treatability testing of VOC-contaminated water. Bench and pilot-scale tests of UV/oxidation and hydrogen peroxide oxidation technologies are completed or will be completed in the future for OU1. If the information from these tests is sufficient to evaluate these technologies for implementation, inclusion of the oxidation technologies as part of the sitewide treatability program will not be necessary. If the test results are inconclusive or are not applicable, the technologies will be identified for testing in the sitewide treatability program. Other pilot scales are in progress or will be performed as part of IM/IRA at OU2 and are reviewed in Section 3.2.

Ozonation, UV photolysis, and slurry phase bioreactor treatment have been identified for pilot-scale testing as part of the Site-wide Program and are presented in Table 4-7. These technologies will continue to be evaluated as described in Figure 4-4 for suitability for pilot-scale testing. Slurry phase bioreactor treatment is applicable to PCB-contaminated soil/sediment. An order of magnitude cost estimate was prepared to provide input into decisions regarding priority and scheduling of future treatability tests. This cost estimate is an engineering judgment based on experience in previous testing for using bioreactors for soil treatment and the EPA guidance document on treatability testing. This cost estimate includes preparation of work plans, assembly of equipment, treatability testing operation, analytical testing, and preparation of a report on results and evaluation.

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TABLES

TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-18
AND UPPER AND LOWER SOUTH INTERCEPT DITCHES

Parameter	Groundwater			Surface Water			Soils			Sediments		
	Maximum*	Minimum**	Potential ARAR	Maximum*	Minimum*	Potential ARAR	Maximum*	Minimum**	Potential** ARAR	Maximum*	Minimum**	Potential** ARAR
METALS (TOTAL AND DISSOLVED) (mg/L)												
Aluminum	37.7	0.200	0.2	293	0.200	0.200	70600	40	30	33900	40	
Antimony	0.628	0.060		0.643	0.060	0.060	57	12		69.7	12	
Arsenic	3.0	0.010	0.05	1.03	0.010	0.05	64	2.0		49.2	2	
Barium	0.943	0.200	1.0	11600	0.200	1.0	1899	40	4000	706	40	
Beryllium	0.04	0.005	0.1	0.170	0.005	0.005	18.3	1.0	0.143	15.5	1.0	
Boron	0.218	5.0	5.0									
Cadmium	0.0352 BR	0.005	0.005	25	0.005	0.005	119	1.0		19.5	1.0	
Calcium	99.9 BR	5.000		1590	5.000		254000	2000		132000	2000	
Cesium	0.4	1.000		12	1.000		2410	2.0	8000(III)	700		
Chromium	0.172 BR	0.010	0.05	0.298	0.010	0.05	781	2.0		64	2.0	
Cobalt	0.22	0.050	0.05	0.489	0.050		88.9	10		43.3	10	
Copper	3.13	0.025	0.2	0.908	0.025	0.025	73.6	5.0		275	5.0	
Iron	76.6	0.100	0.3	3220	0.100	0.30	75900	20		33300	20	
Lead	2.8	0.005	0.05	0.950	0.005	0.005	86.9	1.0		255	1.0	
Lithium	1.79	0.100	2.5	85.2	0.100		100	20		958	20	
Magnesium	788	5.000		391	5.000		23300	2000		103000	2000	
Manganese	11.34	0.015	0.05	27.7	0.015	0.050	3540	3.0		1950	3.0	
Mercury	0.013	0.0002	0.002	3.97	0.0002	0.0002	114	0.2		1.5	0.2	
Molybdenum	1.92 BR	0.200		0.680	0.200		38.65	40		177	40	
Nickel	11.7	0.040	0.2	0.82	0.040	0.4	543	8.0	2000	89.2	8.0	
Phosphorus	1.210	0.040		12	0.040					655	200	

* = Present in laboratory blank
 ** = These are based on human health and environmental risk assessment criteria developed for screening purposes or applicable state or federal requirements
 J = Analyzed below detection limit
 BR = Bedrock (including some weathered bedrock)
 + = Maximum concentration may be a one time measurement
 + + = Value given is detection or quantitation limit for analysis in accordance with Statement of Work for General Radiochemistry and Routine Analytical Services Protocol (G R R A S P) v 1.1 1990 EG&G Rocky Flats Environmental
 (a) = Restoration Program
 (b) = Plutonium 238 + 239 + 240
 (c) = Radium 226 + 228
 (d) = Ammonia as N
 (e) = Sum of polychlorinated biphenyls (PCBs) in water

TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Continued)

Parameter	Groundwater			Surface Water			Soils			Sediments		
	Maximum	Minimum**	Potential ARAR	Maximum*	Minimum*	Potential ARAR	Maximum*	Minimum**	Potential** ARAR	Maximum*	Minimum*	Potential** ARAR
METALS (TOTAL AND DISSOLVED) (Continued) (mg/L)												
Potassium	7050	5 000	0 010	4260	5 000	0 005	8020	2000		67000	2000	
Selenium	100 3	0 005	0 010	0 55	0 005	0 005	6 5	1 0		21 3	1 0	
Silicon	56 4	0 010	0 050	44	0 010	0 010	40 9	2 0	200	2470	4 6	
Silver	0 217	0 010	0 050	0 148	0 010	0 010	44000	2000		411	2 0	
Sodium	4447	5 000	0 050	9080	5 000	0 050	1030	40		1480	2000	
Strontium	82 4	0 200	0 050	11 9	0 200	0 050	5 74	2 0		1230	40	
Thallium	0 544	0 050	0 050	0 029	0 050	0 050	382	40		90	2 0	
Tin	1 121	0 200	0 050	1 53	0 200	0 050	2590	10		1080	40	
Vanadium	0 85	0 050	0 1	1 85	0 050	0 110	487	4 0		90 4	10	
Zinc	5 0	0 020	2 0	28 7	0 020	0 110				735	4 0	
ANIONS (mg/L)												
Ammonia	3151	10		65	0 5	0 5				8590		
Alkalinity as CaCO ₃	2640	10		341	10					3500		
Bicarbonate as CaCO ₃	510	10		4100	10					130		
Chloride	1100	5 0	250	270	5 0	230	20			210		
Cyanide	3 8	0 01	0 2	1200	0 6	0 01	19 8			1 0		
Fluoride	8 2	5 0	5 0	7 7	5 0	5 0						
Nitrate as N	1450	5 0	10 0	1186	5 0	10 0	4 3			35 86		

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TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Continued)

Parameter	Groundwater			Surface Water			Soils			Sediments		
	Maximum*	Minimum*	Potential ARAR	Maximum*	Minimum	Potential ARAR	Maximum	Minimum	Potential** ARAR	Maximum*	Minimum**	Potential*** ARAR
ANIONS (Continued) (mg/L)												
Nitrate + Nitrite as N	12100	5.0	10.0	7800	5.0	10.0	3400			163		
Nitrite as N	1.98	5.0	5.0	430	5.0	5.0				3.1		0.2
Orthophosphate	0.92	0.01		7.9	0.01							
Phosphate	15	0.1		2.1	0.1							
Sulfate	19000	5.0	250	1900	5.0	250	400			744		
Sulfide	13	2.0		120	2.0	2.0	200			23		
Total Kjeldahl Nitrogen				61	1							
Total Organic Carbon				30.9	2		58000					
INDICATORS (mg/L)												
Biochemical O ₂ Demand				260	2.0							
Conductivity Min (umho/cm)				73.7	1.0							
Conductivity Max (umho/cm)				37120	1.0							
Dissolved Oxygen (mg/L)												
Minimum				0.0	0.5	3.0						
Maximum				70	0.5							
Oil and Grease				439	5.0		567			1100		
Percent Solids (%)	32											
Minimum							78.9			14.7		
Maximum							98.4			98.95		

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 (d) = Ammonia as N
 (e) = Sum of polychlorinated biphenyls (PCBs) in water

TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Continued)

Parameter	Groundwater			Surface Water			Soils			Sediments		
	Maximum*	Minimum*	Potential ARAR	Maximum*	Minimum	Potential ARAR	Maximum*	Minimum*	Potential** ARAR	Maximum*	Minimum***	Potential** ARAR
INDICATORS (mg/L)												
pH minimum (pH units)	5.98	0.1	6.5	3.4	0.1	6.5	5.65			6.1		
pH maximum (pH units)	12	0.1	8.5	10.2	0.1	8.5	11.1			9.6		
Temperature (degrees C)												
Minimum				2.0								
Maximum				33								
Total Dissolved Solids (mg/L)	37000	10	400	47000	10	250						
Total Suspended Solids (mg/L)	20000	5.0		46000	5.0							
RADIONUCLIDES (TOTAL AND DISSOLVED) (pCi/L)												
Americium 241	9.68	0.01		90	0.01	30	22	0.02		1.467	0.02	
Cesium 137	7.72	1.0		12	1.0		4.7	0.1		3.2	0.1	
Gross Alpha	2000	2.0	7.0	2107	2.0	7.0	480	4.0	5.0	77	4.0	5.0
Gross Beta	1200	4.0	5.0	3800	4.0	5.0	49.9	10	50.0	53	10	50
Plutonium 238	0.040	0.01	0.05	0.031	0.01					0.016		
Plutonium 239 + 240	8.13	0.01	15(e)	120	0.01	15(e)	180	0.03	0.9	3.3	0.03	0.9
Radium 226	3.54	0.5	5(b)	30	0.5	5(b)	1.9	0.5		1.96	0.5	
Radium 228	13.95	1.0	5(b)	52	0.5	5(b)	2.8	0.5		4.41	0.5	
Strontium 89 + 90	7.52	1.0		4.27	1.0		1.9	1		2.53	1	
Tritium	12.4	1.0	8.0	33.34	1.0	8.0	4.57	1		0.99	1	
	12000	400	500	13000	400	500	3.9	400		580	400	

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TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Continued)

Parameter	Groundwater			Surface Water			Soils			Sediments		
	Maximum*	Minimum**	Potential ARAR	Maximum*	Minimum*	Potential ARAR	Maximum*	Minimum**	Potential** ARAR	Maximum*	Minimum	Potential** ARAR
RADIONUCLIDES (TOTAL AND DISSOLVED) (pCi/L)												
Uranium 233 + 234	1000	0.6		1050	0.6		3.7	0.3		4.11	0.3	
Uranium 233 + 238 + 239	16.9	0.6		14.31	0.6					3.32	0.3	
Uranium 235	47	0.6		65.5	0.6		1.01	0.3		1.34	0.3	
Uranium 235 + 238	6.90	0.6		47.5	0.6					0.15		
Uranium 238	750	0.6		1211	0.6		3.9	0.3		3.82	0.3	
Uranium (Total)	83.7	0.6	5	1023	0.6	5.0	4.0	BR		4.8	0.3	
VOLATILES (ug/L)												
1,1 Dichloroethane	344	5.0		50	5.0		49	5		5.0	J	
1,1 Dichloroethene	48000	5.0	7	143	5.0	7.0	110	5	12000	3.0	J	5.0
1,1,1 Trichloroethane	30250	5.0	200	42	5.0	200	290	5.0	7000000			
1,1,2 Trichloroethane	14740	5.0	5.0	6.0	5.0	5.0	62	5.0	120000			
1,1,2,2 Tetrachloroethane	15	5.0	5	440	5.0	5.0						
1,2 Dichloroethane	16000	5.0	5	23	5.0	5.0	120	5.0	7700			
1,2 Dichloroethene (Total)	14000	5.0	100	460	5.0	100	140	5.0				
1,2 Dichloropropane	6	5.0	5	7.0	5.0	5.0	30	5.0				
1,3 Dichloropropane	3	J		7.0	5.0	10	6.0	J	3900			
2 Butenone	580	10		76	10		530	10.0		12000	10	
2 Chloroethynyl ether				5.0	J		31	J				
2 Hexanone	975	10		87			41	10.0				

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TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Continued)

Parameter	Groundwater			Surface Water			Soils			Sediments		
	Maximum*	Minimum*	Potential ARAR	Maximum	Minimum	Potential ARAR	Maximum	Minimum**	Potential** ARAR	Maximum*	Minimum**	Potential** ARAR
VOLATILES (Continued) (ug/L)												
4-Methyl 2 Pentanone	35	10.0		32	10		120	10		220	10	
Acetone	4100	10.0	4000	970	10	4000	2400	10	8000000	7300	10	
Benzene	83	5.0	5.0	83	5	5	12	10	24000	3.0	10	
Bromochloromethane	1.0	5.0	5.0	6.0	5	700						
Bromoform	1.0	5.0	5.0	3.0	5	700						
Bromomethane	7.0	10.0	10	8.0	10	48	6.0	10	30000			
Carbon Disulfide	28	5.0	4000	29	5.0	4000	150	10	8000000	13	5.0	
Carbon Tetrachloride	28000	5.0	5.0	1005	5.0	5.0	180	5.0	5400			
Chlorobenzene	73	5.0		94	5.0	100	150	55	2000000	4.0	5.0	
Chloroethane	17	10.0		34	10		50	10				
Chloroform	5427	5.0	5.0	84	5.0	5.0	130	5.0	110000	18	5.0	
Chloromethane	17	10.0		38	10					60	10	
Dibromochloromethane				5.0	5.0	6.0						
Ethylbenzene	16	5.0	880	18	5.0	880	780	5.0	8000000	4.0	5.0	
Methylene Chloride	4100	5.0	5.0	340	5.0	5.0	590	BR	93000	16000	5.0	
Styrene	9	5.0	100	6.0	5.0	100	17	J	23000	2.0	5.0	
Tetrachloroethene	528000	5.0	5.0	280	5.0	5.0	10000	5.0	140000	8.0	5.0	
Toluene	270	J	1000	94	5.0	1000	880	5.0	20000000	120	5.0	
Trichloroethene	221880	5.0	5.0	2500	5.0	5.0	17000	5.0	64000	39	5.0	

* = Present in laboratory blank
 ** = These are based on human health and environmental risk assessment criteria developed for screening purposes or applicable state or federal requirements
 J = Analyzed below detection limit
 BR = Bedrock (including some weathered bedrock)
 + = Maximum concentration may be a one time measurement
 + = Value given is detection or quantitation limit for analysis in accordance with Statement of Work for General Radiochemistry and Routine Analytical Services Protocol (G R A S P) v 1.1 1990 EG&G Rocky Flats Environmental Restoration Program
 (a) = Plutonium 238 + 239 + 240
 (b) = Plutonium 226 + 228
 (c) = Americium as N
 (d) = Sum of polychlorinated biphenyls (PCBs) in water

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TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Continued)

Parameter	Groundwater			Surface Water			Soils			Sediments		Potential** ARAR	
	Maximum*	Minimum**	Potential ARAR	Maximum	Minimum**	Potential ARAR	Maximum*	Minimum*	Potential** ARAR	Maximum*	Minimum**		
VOLATILES (Continued) (ug/L)													
Vinyl Acetate	39	J	10	3.0	J	10							
Vinyl Chloride	930		10	25		10				57	J	10	
Xylenes (Total)	50	J	5.0	40		5.0	10000	3300	5.0	200000000	7.0	J	5.0
SEMIVOLATILES (TOTAL) (ug/L)													
Acenaphthene				5.0	J	10	520	57	J	330	2400	J	330
Acenaphthylene											450	J	330
Aldrin				0.06		0.05	0.05						
Alpha BHC				0.01	J	0.05	0.05				4.7	J	8.0
Alpha-chlordane				2.6		0.5	0.5						
Ametryn				0.18		0.06							
Anthracene				2.0	J	10	10	180	J	330	2900	J	330
Atrazine				2720.0		0.05	3.0						
Benzo (a) Anthracene				2.0	J	10	10	120	J	330	7100		330
Benzo (b) Fluoranthene				3.0	J	10	10	350	J	330	7100		330
Benzo (k) Fluoranthene				4.0	J	10	10	320	J	330	6300		330
Benzo (g h i) Pyrene								50	J	330	5700		330
Benzo (a) Pyrene				3.0	J	10.0	10	230	J		6300		330

* = Present in laboratory blank
 ** = These are based on human health and environmental risk assessment criteria developed for screening purposes or applicable state or federal requirements
 J = Analyzed below detection limit
 BR = Bedrock (including some weathered bedrock)
 + = Maximum concentration may be a one-time measurement
 + + = Value given is detection or quantitation limit for analysis in accordance with Statement of Work for General Radiochemistry and Routine Analytical Services Protocol (G R R A S P) v 1.1 1990 EG&G Rocky Flats Environmental
 Restoration Program
 (a) = Plutonium 238 + 239 + 240
 (b) = Plutonium 226 + 228
 (c) = Ammonia as N
 (d) = Sum of polychlorinated biphenyls (PCBs) in water

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TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Continued)

Parameter	Groundwater			Surface Water			Soils			Sediments		
	Maximum*	Minimum*	Potential ARAR	Maximum	Minimum*	Potential ARAR	Maximum*	Minimum*	Potential** ARAR	Maximum	Minimum*	Potential** ARAR
SEMI VOLATILES (TOTAL) (Continued) (ug/L)												
Benzo (k) Pyrene				8.0	J		130	J	330	3300	J	1600
Benzoic Acid				43			400	J	1600			
Benzyl Alcohol				0.1						13000		8.0
Beta-BHC	100	J BR	10	220			18000	*	330	41		330
Bis (2 ethylhexyl) Phthalate										540	J	330
Butyl Benzyl Phthalate	2.0	J	10	3.0	J	10	510	J	330			
Butyl Benzyl Phthalate				1.0	J	10	740		330			
4-Chloro 3 methylphenol							40	J	330			
4-Chlorophenyl Phenyl Ether							550	J	330	8200		330
Chrysene	420		10	2.0	J	10						
Cyanazine				0.3		0.1				95		16
4-4-DDT				0.06	J	0.1				3.2	J	8.0
Delta-BHC				0.02		0.05				1200		330
Dibenzo (a,h) Anthracene										1000	J	
Dibenzofuran				1.0	J							
Dibenz(a,h) Anthracene				2.1		0.27						
Dibenzofuran				4.0	J	10						
1,4-Dichlorobenzene				1.8		0.65						
Dichloroprop				8.0	J	10	31		330	1200		330
Diethyl Phthalate				20	*	10	3643	J	330	3100		330
Di n-Butyl Phthalate	170	J BR	10									

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 ** = These are based on human health and environmental risk assessment criteria developed for screening purposes or applicable state or federal requirements
 J = Analyzed below detection limit
 BR = Bedrock (including some weathered bedrock)
 + = Maximum concentration may be a one-time measurement
 + + = Value given is detection or quantitation limit for analysis in accordance with Statement of Work for General Radiochemistry and Routine Analytical Services Protocol (G R R A S P) v 1.1 1990 EG&G Rocky Flats Environmental Restoration Program
 (a) = Plutonium 238 + 239 + 240
 (b) = Plutonium 226 + 228
 (c) = Ammonia as N
 (d) = Sum of polychlorinated biphenyls (PCBs) in water
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TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Continued)

Parameter	Groundwater			Surface Water			Soils			Sediments		
	Maximum*	Minimum**	Potential ARAR	Maximum*	Minimum**	Potential ARAR	Maximum	Minimum**	Potential** ARAR	Maximum*	Minimum**	Potential** ARAR
SEMI-VOLATILES (TOTAL) (Continued) (ug/L)	(ug/L)			(ug/L)			(ug/kg)			(ug/kg)		
Di-n-Octyl Phthalate	56	J BR	10	24	10		370	J	330	2000	330	
2,4-Dimethylphenol				60	J	10						
2,4-Dinitrotoluene				40	J	10						
Endosulfan	0.04			270						1800	J	80
Ethyl Parathion												
Fluoranthene	10	10		20	J	10	1900		330	16000		
Fluorene				30	J	10	350		330	2000	J	330
Gammie-BHC (Lindane)										50		80
Hexachlorobenzene										440	J	330
Indeno (1,2,3-cd) Pyrene							80	J	330	5000	J	330
Isochlorone				10	J	10						
2-Methylnaphthalene				21	J	10				350	J	330
2-Methylphenol				43		10				2300		330
4-Methylphenol				180		10				2300		330
Naphthalene				25		10				1100	J	330
2-Nitrophenol	30	J	10									
4-Nitrophenol	20	J	50				160	J	1600			
4-Nitroaniline												
N-Nitroso-di-n-Propylamine				5	J	10				5300	J	1600

* = Present in laboratory blank
 ** = These are based on human health and environmental risk assessment criteria developed for screening purposes or applicable state or federal requirements
 J = Analyzed below detection limit
 BR = Bedrock (including some weathered bedrock)
 + = Maximum concentration may be a one time measurement. Values compiled from both recent and historic data checked against Rocky Flats Environmental Data System
 = Value given is detection or quantitation limit for analysis in accordance with Statement of Work for General Radiochemistry and Routine Analytical Services Protocol (S R A S P) v 1.1 1990 EG&G Rocky Flats Environmental Restoration Program
 (a) = Plutonium 238 + 239 + 240
 (b) = Radium 226 + 228
 (c) = Ammonia as N
 (d) = Sum of polychlorinated biphenyls (PCBs) in water

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TABLE 2-1
ANALYTE CONCENTRATIONS FOR COMBINED OPERABLE UNITS 1-16
AND UPPER AND LOWER SOUTH INTERCEPTOR DITCHES
(Concluded)

Parameter	Groundwater			Surface Water			Soils			Sediments		Potential** ARAR
	Maximum	Minimum*	Potential ARAR	Maximum	Minimum	Potential ARAR	Maximum	Minimum**	Potential** ARAR	Maximum*	Minimum**	
SEMI VOLATILES (TOTAL) (Continued) (ug/L)												
N Nitroodiphenylamine	162	*	10	300	10	10	880	J	330	2000	*	330
Pentachlorophenol	4.0	J	50	20	J	50	110	J	1600	350	J	1600
Phenanthrene				6.0	J	10	500	J	330	16000		330
Phenol	1.0	J	10	39		10	320	J	330	660	J	330
Prometon				0.09		0.03						
Prometryn				0.18		0.06						
Propazine				2.4		0.03						
Pyrene				4	J	10	880	J	330	19000		330
Simazine				330		0.06						
Simetryn				0.64		0.07						
Terbutylazine				1.4								
1,2,4-Trichlorobenzene				4		10	700			4.0	J	330
POLYCHLORINATED BIPHENYLS (PCBs) (ug/L)												
Aroclor 1254				12		10	10	440000		0.09	1600000	160

NOTE Analytical data received prior to October 1988 not subjected to validation procedures. Some of the chemical values reported in this table have not yet been validated and the analyte list may be changed after the data are validated.

* = Present in laboratory blank
 ** = These are based on human health and environmental risk assessment criteria developed for screening purposes or applicable state or federal requirements
 J = Analyzed below detection limit
 BR = Bedrock (including some weathered bedrock)
 + = Maximum concentration May be a one-time measurement
 + = Value given is detection or quantitation limit for analysis in accordance with Statement of Work for General Radiochemistry and Routine Analytical Services Protocol (G R A S P) v 1.1 1990 EG&G Rocky Flats Environmental Restoration Program
 (a) = Plutonium 238 + 239 + 240
 (b) = Radium 226 + 228
 (c) = Ammonia as N
 (d) = Sum of polychlorinated biphenyls (PCBs) in water

TABLE 2-2
COMPARISON OF ARARs CHANGES BETWEEN
FINAL TSP AND ANNUAL REPORT

Parameter	Media	Final TSP	Annual Report
<u>Metals (Total and Dissolved) (mg/L)</u>			
Aluminum	Groundwater	5 0	0 2
Antimony	Groundwater	0 01	0
Antimony	Surface Water	0 146	0 060
Antimony	Soil	3000 ug/kg	30 mg/kg
Boron	Groundwater	--	5 0
Cadmium	Groundwater	0 01	0 005
Cadmium	Surface Water	0 01	0 005
Chromium	Soil	400(VI)	8000(III)
Copper	Groundwater	1 0	0 2
Copper	Surface Water	1 0	025
Lead	Surface Water	0 05	0 005
Lithium	Groundwater	--	2 5
Mercury	Surface Water	002	0002
Nickel	Surface Water	0 1	0 4
Selenium	Surface Water	01	005
Silver	Surface Water	05	01
Thallium	Surface Water	--	05
Zinc	Groundwater	5 0	2 0
Zinc	Surface Water	5 0	110
<u>Anions (mg/L)</u>			
Chloride	Surface Water	250	230
Cyanide	Groundwater	10	0 2
Cyanide	Surface Water	10	01
Fluoride	Surface Water	--	5
Nitrite as N	Groundwater	--	5
<u>Indicators (mg/L)</u>			
Dissolved Oxygen (min)	Groundwater	--	3

TABLE 2-2
COMPARISON OF ARARs CHANGES BETWEEN
FINAL TSP AND ANNUAL REPORT
(continued)

Parameter	Media	Final TSP	Annual Report
Total Dissolved Solids	Groundwater	500	400
Total Dissolved Solids	Groundwater	500	250
Radionuclides (Total and Dissolved) (pCi/L)			
Gross Alpha	Groundwater	15	7
Gross Alpha	Surface Water	15	7
Gross Beta	Groundwater	50	5
Radium 226	Groundwater	--	5
Radium 228	Groundwater	--	5
Tritium	Groundwater	20,000	500
Uranium (Total)	Groundwater	--	5
Volatiles (ug/L)			
1,1,2-Trichloroethane	Groundwater	28	5
1,1,2-Trichloroethane	Surface Water	--	5
1,1,2,2-Tetrachloroethane	Groundwater	--	5
1,1,2,2-Tetrachloroethane	Surface Water	--	5
1,2-Dichloroethene (Total)	Groundwater	70	100
1,2-Dichloroethene (Total)	Surface Water	70	100
1,2, Dichloropropane	Surface Water	--	5
1,3-Dichloropropene	Surface Water	--	10
Benzene	Soil	--	24,000
Bromodichloromethane	Groundwater	--	5 0
Bromodichloromethane	Surface Water	--	700
Bromoform	Groundwater	--	5 0
Bromoform	Surface Water	--	700
Bromomethane	Groundwater	--	10
Bromomethane	Surface Water	--	48

TABLE 2-2
COMPARISON OF ARARs CHANGES BETWEEN
FINAL TSP AND ANNUAL REPORT
(continued)

Parameter	Media	Final TSP	Annual Report
Bromomethane	Soil	--	30,000
Carbon disulfide	Groundwater	--	4000
Carbon disulfide	Surface Water	--	4000
Carbon disulfide	Soil	--	8,000,000
Chloroform	Groundwater	100	5
Chloroform	Surface Water	100	5
Dibromochloromethane	Surface Water	--	6
Ethylbenzene	Surface Water	1400	680
Styrene	Groundwater	--	100
Styrene	Surface Water	--	100
Styrene	Soil	--	23,000
Tetrachloroethene	Groundwater	10	5
Toluene	Groundwater	2420	1000
Toluene	Surface Water	14,300	1000
Xylenes (Total)	Groundwater	7,000	10,000
Xylenes (Total)	Surface Water	7,000	10,000
Semivolatiles (Total) (ug/L)			
Acenaphthene	Surface Water	--	520
Aldrin	Surface Water	--	05
Alpha-BHC	Surface Water	--	05
Alpha-chlordane	Surface Water	--	5
Anthracene	Surface Water	--	10
Atrazine	Surface Water	--	3 0
Benzo(a)Anthracene	Surface Water	--	10
Benzo(b)Fluoranthene	Surface Water	--	10
Benzo(k)Fluoranthene	Surface Water	--	10
Benzo(a)Pyrene	Surface Water	--	10

TABLE 2-2
COMPARISON OF ARARs CHANGES BETWEEN
FINAL TSP AND ANNUAL REPORT
(continued)

Parameter	Media	Final TSP	Annual Report
Beta-BHC	Surface Water	--	05
Bis(2-ethylhexyl)Phthalate	Surface Water	15,000	10
Butyl Benzyl Phthalate	Surface Water	--	3,000
4-Chloro-3-methylphenol	Surface Water	--	30
Chrysene	Surface Water	--	10
4,4-DDT	Surface Water	--	1
1,4-Dichlorobenzene	Surface Water	--	75
Diethyl Phthalate	Surface Water	--	23,000
Di-n-Butyl Phthalate	Groundwater	4	10
Di-n-Butyl Phthalate	Surface Water	4	10
2,4-Dimethylphenol	Surface Water	--	2120
2,4-Dinitrotoluene	Surface Water	--	10
Ethyl Parathion	Surface Water	--	0 13
Fluoranthene	Surface Water	--	42
Fluorene	Surface Water	--	10
Isophorone	Surface Water	--	10
Napthalene	Surface Water	--	10
N-Nitroso-di-n-Propylamine	Surface Water	--	10
N-Nitrosodiphenylamine	Groundwater	--	10
N-Nitrosodiphenylamine	Surface Water	--	10
Pentachlorophenol	Groundwater	--	50
Pentachlorophenol	Surface Water	--	50
Pentachlorophenol	Soil	--	200,000
Phenol	Groundwater	--	10
Phenol	Surface Water	3500	10
Phenol	Soil	--	3,000,000
Pyrene	Surface Water	--	10

TABLE 2-2
COMPARISON OF ARARs CHANGES BETWEEN
FINAL TSP AND ANNUAL REPORT
(continued)

Parameter	Media	Final TSP	Annual Report
Simazine	Surface Water	--	4
1,2,4-Trichlorobenzene	Surface Water	--	700
Aroclor-1254	Surface Water	--	1 0
Aroclor-1254	Soil	--	09

TABLE 2-3

**LIST OF CHEMICALS REPORTED ABOVE
ARARs IN TWO OR MORE OPERABLE UNITS**

Contaminant	Operable Units (Two or More)			
	Reported in Groundwater	Reported in Surface Water	Reported in Soils	Reported in Sediments
METALS				
Aluminum	1, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, USID		
Antimony		2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16, LSID		
Arsenic	4, 6, 7, 10, 14, 16	5, 6, BACK		
Barium		2, 4, 5, 6, 7, 8, 10, 14, 16, USID, LSID		
Beryllium		2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16, LSID	1, 2, 4, 5, 6, 8, 9, 10, 12, 13, 14, 15, 16	
Cadmium	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 14, 16	2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16, LSID		
Chromium	2, 4, 5, 6, 8, 10, 11, 13, 14, 16	2, 4, 5, 6, 7, 8, 10, 13, 14, 16 USID, LSID		
Cobalt	1, 2, 4, 6, 7, 8, 10, 14, 16			
Copper	1, 2, 4, 5, 6, 7, 8, 10, 14, 16	2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16		
Iron	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16 LSID, USID		

BACK = Sitewide Background Maximum
 USID = Upper South Interceptor Ditch
 LSID = Lower South Interceptor Ditch

TABLE 2-3

**LIST OF CHEMICALS REPORTED ABOVE
ARARs IN TWO OR MORE OPERABLE UNITS
(Continued)**

Contaminant	Operable Units (Two or More)			
	Reported in Groundwater	Reported in Surface Water	Reported in Soils	Reported in Sediments
Lead	2, 4, 5, 6, 8, 9, 10, 11, 14, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, LSID, USID		
Manganese	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, LSID, USID		
Mercury	1, 2, 4, 5, 8, 10, 11, 14, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 16,		
Nickel	1, 2, 4, 5, 6, 7, 8, 9, 10, 14, 16	2, 4, 5, 6, 8, 10, 13, 14, 16, BACK		
Selenium	1, 2, 4, 5, 6, 7, 8, 9, 10, 14, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16, LSID		
Silver	2, 6, 7, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16		
Thallium		6, 16		
Vanadium	2, 6, 7, 8, 9, 10, 13, 16			
Zinc	1, 2, 5, 6, 8, 10, 14, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 16		
INORGANICS				
Chloride	1, 4, 7	4, 7		
Cyanide	2, 4, 6, 8, 9, 10, 14, 16	2, 5, 6, 7, 8, 9, 10, 13, 14, 16		

BACK = Sitewide Background Maximum
 USID = Upper South Interceptor Ditch
 LSID = Lower South Interceptor Ditch

TABLE 2-3
LIST OF CHEMICALS REPORTED ABOVE
ARARs IN TWO OR MORE OPERABLE UNITS
(Continued)

Contaminant	Operable Units (Two or More)			
	Reported in Groundwater	Reported in Surface Water	Reported in Soils	Reported in Sediments
Nitrate and Nitrate + Nitrite	4, 6, 8, 10, 14, 16	1, 2, 4, 8		
Sulfate	1, 2, 4	4, 5, 7		
pH below minimum		1, 2, 4, 5, 6, 7, LSID, USID		
pH above maximum	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	6, 7, 9, LSID, USID		
Total Dissolved Solids	1, 2, 4, 7	1, 4, 5, 6, 7, 11, LSID		
RADIONUCLIDES				
Americium 241		2, 4, 8, 10, 14, 16		
Gross Alpha	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16, LSID, USID	1, 2, 4, 5, 6, 8, 9, 10, 11, 13, 14, 15, 16	1, 5, 6, 8, 9, 10, 13, 14, 15, 16
Gross Beta	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, LSID, USID		
Plutonium 239 + 240		2, 4, 8, 10, 14, 16	1, 2, 4, 6, 8, 10, 13, 14, 16	5, 6, 8, 9, 10, 14, 16
Radium 226	4, 6, 8, 10, 14, 16	2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16, LSID, BACK		
Radium 228	4, 8, 10, 16	2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16		

BACK = Sitewide Background Maximum
USID = Upper South Interceptor Ditch
LSID = Lower South Interceptor Ditch

TABLE 2-3

**LIST OF CHEMICALS REPORTED ABOVE
ARARs IN TWO OR MORE OPERABLE UNITS
(Continued)**

Contaminant	Operable Units (Two or More)			
	Reported in Groundwater	Reported in Surface Water	Reported in Soils	Reported in Sediments
Strontium 90	2, 5, 6, 7, 8, 10, 16			
Tritium	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 16		
Uranium (Total)	1, 2, 4, 6, 7, 8, 9, 11, 13, 14, 15, 16	1, 2, 4, 5, 6, 8, 9, 10, 13, 14, 16, USID		
VOLATILE ORGANICS				
1,1-Dichloroethene	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16	2, 6, 8, 9, 10, 13, 14, 16		
1,1,1-Trichloroethane	1, 2, 4, 8, 10, 14, 15, 16			
1,1,2-Trichloroethane	1, 2, 5, 10, 12, 14, 15, 16	6		
1,1,2,2-Tetrachloroethane		4, 6, 8, 10, 14, 16		
1,2 - Dichloroethane	1, 2, 4, 6, 8, 10, 13, 14, 16			
1,2 - Dichloroethene (total)	1, 2, 4, 5, 6, 8, 9, 10, 13, 14, 15, 16	2, 8, 9, 10, 13, 14, 16		
1,2-Dichloropropane	7, 16			
Benzene	1, 4, 7, 8, 10, 11, 14, 16			
Carbon Tetrachloride	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16	2, 5, 6, 8, 9, 10, 13, 14, 16		

BACK = Sitewide Background Maximum
 USID = Upper South Interceptor Ditch
 LSID = Lower South Interceptor Ditch

TABLE 2-3

**LIST OF CHEMICALS REPORTED ABOVE
ARARs IN TWO OR MORE OPERABLE UNITS
(Concluded)**

Contaminant	Operable Units (Two or More)			
	Reported in Groundwater	Reported in Surface Water	Reported in Soils	Reported in Sediments
Chloroform	1, 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 16	2, 5, 6, 8, 9, 10, 13, 14, 16		
Methylene Chloride	1, 2, 4, 5, 6, 7, 9, 10, 11, 12, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, LSID		
Tetrachloroethene	1, 2, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16	1, 2, 5, 6, 7, 8, 9, 10, 13, 14, 16		
Trichloroethene	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 5, 6, 7, 8, 9, 10, 13, 14, 16, LSID		
Vinyl Chloride	6, 7, 9, 10, 13, 14, 15, 16	6, 8, 9, 10, 13, 14, 16		
SEMIVOLATILE ORGANICS				
Alpha-Chlordane		1, 9		
Bis(2-ethylhexyl)phthalate	5, 6, 9, 13	5, 6, 8, 10, 16		
Di-N-Butyl Phthalate		5, 6		
Naphthalene		6, 7, 16		
N-Nitrosodiphenylamine	1, 2, 5, 6, 7, 8, 10, 11, 16	5, 6, 13		
Phenol		5, 6, 7		
POLYCHLORINATED BIPHENYLS (PCBs)				
Aroclor-1254		6, 8, 10, 16	8, 10, 12, 13	

BACK = Sitewide Background Maximum
 USID = Upper South Interceptor Ditch
 LSID = Lower South Interceptor Ditch

TABLE 4-1A

**TECHNOLOGIES IDENTIFIED FOR PRELIMINARY SCREENING
GROUNDWATER AND SURFACE WATER**

VOLATILE ORGANICS	
<u>Physical Processes</u>	<u>Chemical Processes</u>
Aqua Detox (Low Vacuum Steam Stripping)	Catalytic Oxidation
In Situ Air Stripping	Solar Photocatalytic (1)
<u>Biological Processes</u>	<u>Thermal Processes</u>
Aerobic Biological Reactors	No Additional Technologies
Aerobic Reductive Dechlorination	or New Information
Cometabolism Biological Process	
SEMIVOLATILE ORGANICS	
<u>Physical Processes</u>	<u>Chemical Processes</u>
Aqua Detox (Low Vacuum Steam Stripping)	Catalytic Oxidation
Carbon Dioxide Extraction	Solar Photocatalytic (1)
<u>Biological Processes</u>	<u>Thermal Processes</u>
Anaerobic Biological Activated Carbon Process	Supercritical Water Oxidation (1)
Anaerobic Reductive Dechlorination	
Cometabolism Biological Process	
Contact Stabilization	
Extended Aeration	
In Situ Bioremediation (1)	
Pure Oxygen Activated Sludge	
PCBs	
<u>Physical Processes</u>	<u>Chemical Processes</u>
Activated Carbon	Catalytic Oxidation
Freeze Crystallization	Ozonation
Solvent Extraction	Peroxide Oxidation
	Solar Photocatalytic
	Ultraviolet Oxidation
	Ultraviolet Photolysis
<u>Biological Processes</u>	<u>Thermal Processes</u>
Anaerobic Biological Activated Carbon Process	Solar
Powdered Activated Carbon	Supercritical Water Oxidation

(1) Denotes technology has been reevaluated based on additional information and review

TABLE 4-1A

**TECHNOLOGIES IDENTIFIED FOR PRELIMINARY SCREENING
GROUNDWATER AND SURFACE WATER
(Concluded)**

INORGANICS	
<u>Physical Processes</u>	<u>Chemical Processes</u>
No Additional Technologies or New Information	Catalytic Oxidation
<u>Biological Processes</u>	<u>Thermal Processes</u>
Biodenitrification	No Additional Technologies or New Information
METALS	
<u>Physical Processes</u>	<u>Chemical Processes</u>
Alternating Current Electro-Coagulation Hardwicka Binata Bark Adsorption Ultrafiltration	No Additional Technologies or New Information
<u>Biological Processes</u>	<u>Thermal Processes</u>
Activated Sludge Biosorption (Bioaccumulation) (1)	No Additional Technologies or New Information
RADIONUCLIDES	
<u>Physical Processes</u>	<u>Chemical Processes</u>
Alternating Current Electrocoagulation Emulsion Liquid Membrane Extraction Hollow-Fiber Supported Liquid Membrane	Potassium Ferrate Precipitation (TRU- Clear™)(1)
<u>Biological Processes</u>	<u>Thermal Processes</u>
Biosorption (Bioaccumulation) (1) Enzymatic Microbial Reduction	No Additional Technologies or New Information

(1) Denotes technology has been reevaluated based on additional information and review

TABLE 4-1B

**TECHNOLOGIES IDENTIFIED FOR PRELIMINARY SCREENING
SOIL AND SEDIMENTS**

PCBS	
<u>Biological Processes</u>	<u>Physical/Chemical Processes</u>
Aerobic Biodegradation	B E S T Process
Anaerobic Biological Activated Carbon Process	CF Systems Organic Extraction
Anaerobic Dechlorination	Fenton's Reagent Decomposition
Slurry Phase Bioreactor	Glycolate Dechlorination
	Surfactant Washing
<u>Thermal Processes</u>	<u>Solidification/Stabilization Processes</u>
Fluidized Bed Incineration	Chemical Stabilization
Infrared Thermal Treatment	In Situ Vitrification
Rotary Kiln Incineration	Vitrification
Solar	
Wet Air Oxidation	
METALS	
<u>Biological Processes</u>	<u>Physical/Chemical Processes</u>
No Additional Technologies or New Information	No Additional Technologies or New Information
<u>Thermal Processes</u>	<u>Solidification/Stabilization Processes</u>
No Additional Technologies or New Information	In Situ Vitrification (1)
RADIONUCLIDES	
<u>Biological Processes</u>	<u>Physical/Chemical Processes</u>
No Additional Technologies or New Information	No Additional Technologies or New Information
<u>Thermal Processes</u>	<u>Solidification/Stabilization Processes</u>
No Additional Technologies or New Information	In Situ Vitrification (1)
	Polymerization - Polyethylene (1)

(1) Denotes technology has been reevaluated based on additional information and review

TABLE 4-2A

PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Volatile Organics Physical		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Applicability								
Aqua Detox (Low vacuum steam stripping)	Applicable to volatile and semivolatile contaminants in groundwater		95 + % achievable	Yes	Commercially available	Complex operations Requires steam	Equipment available	Produces reduced volume solvent stream which requires disposal	Yes
In Situ Air Stripping	Applicable to most volatile contaminants in groundwater Most effective in high permeability soils		95 + % achievable	Yes	Innovative	High for emission control system	Requires installation of horizontal air injection/extraction wells below/above aquifer Will likely require treatment of air emissions	Potential for uncontrolled release of volatile contaminants	Yes

TABLE 4-2A

PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Volatile Organics Chemical								
Technology	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No	
Solar Photocatalytic	Potentially applicable to most VOC compounds	Up to 95%	Unknown	Innovative	Unknown	Equipment not currently commercially available	No major impacts identified	No ¹	
Catalytic Oxidation	Potentially applicable to most VOC compounds	Unknown	Unknown	Experimental	Unknown	Research into selection of appropriate catalysts in progress Equipment not currently available	No major impacts identified	No ¹	

¹ See Table 4-4A for rejection rationale. Technologies that have not been retained are shaded.

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Volatile Organics Biological	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Aerobic Biological Reactors	Applicable to volatile petroleum hydrocarbons (BTEX) Not applicable to chlorinated solvents	95 + % achievable	Yes	Innovative for application to surface water and groundwater remediation	Close operator- attention and good process control required	Various types of reactor systems available	Potential for VOC emissions to air Produces bio- mass sludge which must be disposed	Yes	
Aerobic Reductive Dechlorination	Applicable to chlorinated solvents in water	Unknown	Unknown	Innovative	Unknown	Equipment not commercially available	Unknown	No ¹	
Cometabolism Biological Process	Applicable to chlorinated solvents in water	50 to 60%	No	Emerging	Unknown	Equipment not commercially available	Unknown	No ¹	

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Volatile Organics Thermal	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No

No additional technologies or new information on
previously identified technologies in Final TSP

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group
Technology Group

Semivolatile Organics
Physical

Technology	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Aqua Detox (Low Vacuum Steam Stripping)	Applicable to volatile and semivolatile compounds in water	95 + % achievable	Yes	Commercially available	Complex operation Requires steam	Equipment available	Produces a reduced volume solvent stream which requires disposal	Yes
Carbon Dioxide Extraction	Applicable to most semivolatile compounds in water	Unknown	Unknown	Innovative	Unknown	Unknown	Unknown	No ¹

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	<u>Semivolatile Organics</u> <u>Chemical</u>	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Catalytic Oxidation	Potentially applicable to most semivolatile compounds in water	Unknown	Unknown	Experimental	Unknown	Research into selection of appropriate catalysts in progress Equipment not commercially available	No major impacts identified	No ¹
Solar Photocatalytic	Potentially applicable to most semivolatile compounds in water	Up to 95%	Unknown	Innovative	Unknown	Equipment not commercially available	No major impacts identified	No ¹

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Semivolatile Organics Biological	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Anaerobic Biological Activated Carbon Process	Wide range of organics	Highly variable potentially 90%	Requires polishing step	Experimental	Unknown	Equipment not commercially available	Unknown	No ¹	
Anaerobic Reductive Dechlorination	Applicable to chlorinated semi- volatile organics in water	Unknown	Unknown	Innovative	Unknown	Equipment not commercially available	Unknown	No ¹	
Cometabolism Biological Process	Applicable to chlorinated organics, phenol, cresol	50 to 60%	No	Emerging	Unknown	Equipment not commercially available	Unknown	No ¹	
Contact Stabilization	Wide range of organics	85 to 90%	Requires polishing step	Available	Moderate	Equipment readily available	Produces sludge which will require disposal	Yes	
Extended Aeration	Wide range of organics	80 to 90%	Requires polishing step	Available	Moderate	Equipment readily available	Produces sludge which will require disposal	Yes	

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	<u>Semivolatile Organics</u> <u>Biological</u>	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
In Situ Bioremediation	Wide range of organics	High for high initial concentrations Not effective at low concentrations	Low	Innovative	Moderate	Requires careful design of extraction and injection wells	No significant impacts	No ¹
Pure Oxygen Activated Sludge	Wide range of organics	90 to 95%	Requires polishing step	Available	High	Equipment readily available	Produces sludge which will require disposal	Yes

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Semi-volatile Organics Thermal		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Applicability								
Supercritical Water Oxidation	Most semi-volatile organics in water		99 + % achievable	Yes	Commercially available Innovative in remediating of groundwater and surface water	High energy requirement High pressure operation Potential problems with this technology due to process operating conditions, complexity, and lack of long-term full-scale operating experience	Not Readily implementable, Requires very specialized equipment	No major impacts identified	Yes

**TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER**

Contaminant Group Technology Group	PCBs Physical	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Activated Carbon		Applicable to PCBs in water at low to moderate concentrations	High	High	Commercially available	High requirement for replacement of carbon	Equipment commercially available	Disposal of PCB contaminated carbon may be a problem	Yes
Freeze Crystallization		Applicable to dilute concentrations of PCB in water	High	High	Commercially available	Moderate Requires high power use for refrigeration	Equipment commercially available	Produces concentrated waste stream which must be treated or disposed	Yes
Solvent Extraction		Applicable to high concentrations of PCBs in water	High at high initial concentra- tions Choice of solvents critical	Low to Moderate	Commercially available	Moderate	Equipment commercially available	Produces concentrated waste stream which must be treated or disposed	No ¹

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	PCBs Chemical	Technology	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Catalytic Oxidation		Potentially applicable to PCBs in water	Unknown	Unknown	Experimental	Unknown	Research into selection of appropriate catalysts in progress. Equipment not commercially available	No major Impacts Identified	No ¹	
Ozonation		Applicable to PCBs in water Not a specific treatment	Medium to high Very compound specific	Yes	Commercially available	Low High chemical demand	Equipment available	No significant Impacts	Yes	
Peroxide Oxidation		Applicable to PCBs in water Not a specific treatment	Medium to high Very compound specific	Yes	Commercially available	Low High chemical demand	Equipment available	No significant Impacts	Yes	
Solar Photocatalytic		Potentially applicable to PCBs in water	Unknown	Unknown	Innovative	Unknown	Equipment not commercially available	Unknown	No ¹	
Ultraviolet Oxidation		Applicable to PCBs in water Not a specific treatment	Medium to high Very compound specific	Yes	Yes	Commercially available	Low Requires periodic maintenance of UV lamps High power requirement	No major impacts	Yes	

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	PCBs Chemical		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Applicability								
Ultraviolet Photolysis	Applicable to PCBs in water Not a specific treatment		Medium to high Very compound specific	Yes	Yes	Commercially available	Low Requires periodic maintenance of UV lamps High power requirement	No major impacts	Yes

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	PCBs Biological	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Anaerobic Biological activated Carbon Process	Potentially applicable	Unknown	Unknown	Not demonstrated	Unknown	Equipment not commercially available	Unknown	No ¹
Powdered Activated Carbon	Applicable to wide range of concentrations of PCBs in water	High	Yes	Commercially available	Moderate	Equipment is commercially available	Produces PCB contaminated waste sludge requiring treatment/ disposal	Yes

¹ See Table 4-4A for rejection rationale. Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	PCBs Thermal	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Solar		Applicable to PCBs and other chlorinated hydrocarbons	Unknown	Unknown	Under development	Unknown	Unknown	No major impacts identified	No ¹
Supercritical Water Oxidation		Applicable to PCBs in water	99+ % to PCBs achievable	Yes	Commercially available Innovative in remediation of surface water and groundwater	High energy requirement High pressure operation	Equipment commercially available	No major impacts identified	Yes

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Inorganics Physical	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No

No additional technologies or new information on
previous technologies identified

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group
Technology Group

Inorganics
Chemical

Technology	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Catalytic Oxidation	Applicable to cyanide in water	Unknown	Unknown	Innovative	Unknown	Not commercially available	Unknown	No ¹

¹ See Table 4-4A for rejection rationale. Technologies that have not been retained are shaded.

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Inorganics Biological		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Technology								
Biodenitrification	Applicable to nitrates in water	99 + % achievable	Yes	Demonstrated	Requires addition of organic substrate	Good process control required	Readily available	No major impacts identified	Yes

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Inorganics Thermal		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No

No additional technologies or new information on
previously identified technologies in Final TSP

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Metals Physical	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Alternating Current Electro- coagulation		Applicable to most metals in water. Must be combined with solids removal step	Unknown	Unknown	Innovative	Requires good process control	Equipment not commercially available	No major impacts identified	No ¹
Hardwickia Binata Bark Adsorption		Applicable to mercury (II) in water	Unknown	Unknown	Experimental	Unknown	Equipment not commercially available	No major impacts identified	No ¹
Ultrafiltration		Applicable to insoluble metal species in water or metals complexed with high molecular weight molecules	High Dependent on ability to precipitate or complex metals	Unknown	Commercially available	Frequent maintenance of filtration membranes	Readily implementable	No major impacts identified	Yes

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	<u>Metals</u> <u>Chemical</u>		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Technology	Applicability							

No additional technologies or new information on
previously identified technologies in Final TSP

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	<u>Metals</u> <u>Biological</u>	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Activated Sludge		Applicable to most metals in water	Moderate to high	Moderate	Activated sludge treatment commercially available	Moderate	Requires operation of activated sludge water treatment system	Solid sludge from process will contain metals removed. May be hazardous waste	No ¹
Biosorption (Bioaccumulation)		Applicable to most metals in water	Unknown	Low	Experimental	Unknown	Utilizes conventional equipment	Solid sludge from process will contain metals removed. May be hazardous waste	No ¹

¹ See Table 4 4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	<u>Metals</u> <u>Thermal</u>		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No

No additional technologies or new information on
previously identified technologies in Final TSP

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Radionuclides Physical	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Alternating Current Electrocoagulation		Applicable to removal of uranium and transuranium elements from water. Must be combined with solids removal treatment	High	Yes	Innovative	Requires good process control	Equipment available	No major impacts identified	Yes
Emulsion Liquid Membrane Extraction		Applicable to uranium contaminated water	Unknown	Unknown	Experimental	Unknown	Not commercially available	No major impacts identified	No ¹
Hollow-Fiber Supported Liquid Membrane		Applicable to uranium- contaminated water	Unknown	Unknown	Experimental	Unknown	Not commercially available	No major impacts identified	No ¹

¹ See Table 4-4A for rejection rationale. Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Radionuclides Chemical		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Technology	Applicability							
Potassium Ferrate Precipitation (TRU Clear™)		Applicable to removal of uranium and transuranium elements from water. Must be combined with solids removal treatment	High	Yes	Innovative	Requires good process control	Equipment available	No major impacts identified	Yes

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Radionuclides Biological	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Biosorption (Bioaccumulation)		Potentially applicable to metallic radionuclides	Unknown	Unknown	Experimental	Unknown	Not commercially available	Produces a solid waste containing radionuclides	No ¹
Enzymatic Microbial Reduction		Applicable to uranium dissolved in water	Unknown	Unknown	Experimental	Unknown	Not commercially available	No major impacts identified	No ¹

¹ See Table 4-4A for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2A
PRELIMINARY TECHNOLOGY SCREENING
GROUNDWATER AND SURFACE WATER

Contaminant Group Technology Group	Radionuclides		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Thermal								

No new technologies or new information on
previously identified technologies in Final TSP

TABLE 4-2B

**PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS**

Contaminant Group Technology Group	PCBs Biological	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Aerobic Biodegradation		Applicable to PCB- contaminated soils	Highly variable, 10 to 50% typical	Unknown	Innovative	Unknown	Not commercially available	Unknown	No ¹
Anaerobic Biological Activated Carbon Process		Potentially applicable	Unknown	Unknown	Not demonstrated	Unknown	Not commercially available	Unknown	No ¹
Anaerobic Dechlorination		Applicable to PCB contaminated soils	Unknown	Unknown	Experimental	Unknown	Not commercially available	Unknown	No ¹
Slurry Phase Bioreactor		Applicable to PCB/PCE- contaminated soils	Highly variable	Unknown	Innovative	High materials handling	Uses conventional equipment	Produces liquid waste stream	Yes

¹ See Table 4-4B for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	PCBs Physical/Chemical Process		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Applicability								
BEST Process	Applicable to sludges and sediments containing organic contaminants		Low to Medium	Low	Innovative	High materials handling	Equipment available	Produces waste stream containing contaminants removed	No ¹
CF Systems Organic Extraction System	Applicable to sludges and sediments containing organic contaminants		70%	Moderate	Innovative	High materials handling	Equipment available	Produces waste stream containing contaminants removed Produces large volume of residues	No ¹
Fenton's Reagent Decomposition	Applicable to PCB/PCE- contaminated soils		77% for PCBs	Moderate	Experimental	Unknown	Unknown	No major impacts identified	No ¹
Glycolate Dechlorination	Applicable to soils containing PCBs or highly concentrated chlorinated organics		Variable	Moderate	Innovative	High materials handling	Equipment available	Produces waste stream	No ¹
Surfactant Washing	Applicable to PCB contaminated soils		Low to Medium	Low	Innovative	High materials handling	Uses readily available equipment	Produces waste stream containing contaminants removed	No ¹

¹ See Table 4-4B for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	PCBs Thermal	Applicability	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Fluidized Bed Incineration		Applicable to PCBs and a wide range of VOCs	High	High	Commercially available	Requires supplemental fuel	Requires off-gas treatment, mobile units available Excavation required	No major impacts identified	Yes
Infrared Thermal Treatment		Applicable to PCB, VOC and semi- volatile contaminated soils	Moderate to High	High	Commercially available	Requires supplemental fuel, moving parts in thermal zone	Requires off-gas treatment, mobile units available Excavation required	No major impacts identified	Yes
Rotary Kiln Incineration		Applicable to PCBs and a wide range of VOCs	High	High	Commercially available	Requires supplemental fuel	Requires off-gas treatment, mobile units available Excavation required	No major impacts identified	Yes
Solar		Applicable to PCB/PCE- contaminated soils	Unknown	Unknown	Innovative	Unknown	Not commercially available	No major impacts identified	No ¹
Wet Air Oxidation		Applicable to PCB, volatile and semi- volatiles	Variable	Moderate	Pilot scale	Complex process, high temperature and pressure	Equipment not readily available	Produces off-gas	No ¹

¹ See Table 4-4B for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	PCBs Solidification/Stabilization	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Chemical Stabilization	Applicable to soil containing PCBs and creosote and incinerator ash containing heavy metals	N/A*	N/A*	Innovative	Unknown	Unknown	Unknown	No ¹
In Situ Vitrification	Applicable to semivolatile organics, metals, radionuclides and PCBs in soil	High	High	Demonstrated on pilot scale	Complex field activity required	Currently withdrawn from market due to operational problems	Off-gas may need treatment	No ¹
Vitrification	Applicable to semivolatile organics, metals, radionuclides and PCBs in soil	High	High	Demonstrated	High	Commercial capacity unknown	Off-gas may need treatment	No ¹

* N/A refers to fact that these technologies do not remove or destroy contaminants. However, passing EP Tox or TCLP may achieve clean-up goals

¹ See Table 4-4B for rejection rationale. Technologies that have not been retained are shaded

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	<u>Metals</u> <u>Biological</u>	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Technology	Applicability							

No new technologies or new information on previously identified technologies in Final TSP

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	Metals Thermal	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
		Applicability						

No new technologies or new information on previously identified technologies in Final TSP

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	Metals <u>Physical/Chemical</u>		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Applicability								

No new technologies or new information on previously identified
technologies in Final TSP

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	Metals Solidification/Stabilization		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Applicability								
In Situ Vitrification	Applicable to most metals in soil		N/A ¹	N/A ¹	Developing	High energy use Labor intensive	Currently withdrawn from commercial availability due to operational problems	Potential for toxic emissions May not be implement- able near building foundations or areas of buried utilities	No ¹

N/A refers to the fact that these technologies do not remove or destroy contaminants However, passing EP Tox or TCLP may achieve cleanup goals

¹ See Table 4-4B for rejection rationale Technologies that have not been retained are shaded

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	Radionuclides Biological	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Technology	Applicability							

No new technologies or new information on previously identified technologies in Final TSP

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	Metals <u>Physical/Chemical</u>	Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
Technology	Applicability							

No new technologies or new information on previously identified technologies in Final TSP

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	Metals Thermal		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Applicability								

No new technologies or new information on previously identified technologies in Final TSP

TABLE 4-2B
PRELIMINARY TECHNOLOGY SCREENING
SOIL AND SEDIMENTS

Contaminant Group Technology Group	Metals <u>Solidification/Stabilization</u>		Removal Efficiency	Potential to Meet Cleanup Goal	Technology Maturity	O & M Requirements	Implementability	Adverse Impacts	Retain Yes/No
	Applicability								
In Situ Vitrification	Applicable to most radionuclides in soils		N/A*	N/A*	Developing	High energy use Labor intensive	Currently withdrawn from commercial availability due to operational	Potential for toxic emissions May not be implemen- table near building foundations or areas with buried utilities	No*
Polymerization- Polyethylene	Low level radioactive wastes		N/A*	N/A*	Innovative	High	Equipment available	Increased waste volume	No ¹

N/A refers to the fact that these technologies do not remove or destroy contaminants However, passing EP Tox or TCLP may achieve cleanup goals

See Table 4-4B for rejection rationale Technologies that have not been retained are shaded

TABLE 4-3A
SUMMARY OF GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
RETAINED AFTER PRELIMINARY SCREENING

Contaminant Group	Physical Treatments	Chemical Treatments	Biological Treatments	Thermal Treatments
Volatile Organics	Aqua Detox (Low Vacuum Steam Stripping) In Situ Air Stripping		Aerobic Biological Reactors	
Semivolatile Organics	Activated Carbon (1) Aqua Detox (Low Vacuum Steam Stripping) Freeze Crystallization (1) Steam Stripping (1)	Catalytic Dechlorination (1) Gamma Irradiation (1) Ozonation (1) Peroxide Oxidation (1) Ultraviolet Oxidation (1) Ultraviolet Photolysis (1)	Contact Stabilization Extended Aeration Powdered Activated Carbon (1) Pure Oxygen Activated Sludge Submerged Aerobic Fixed Film Reactor (1)	Steam Stripping/Catalytic or Thermal Oxidation (1) Supercritical Water Oxidation
PCBs	Activated Carbon Freeze Crystallization	Ozonation Peroxide Oxidation Ultraviolet Oxidation Ultraviolet Photolysis	Powdered Activated Carbon	Supercritical Water Oxidation
Inorganics			Biodenitrification	
Metals	Ultrafiltration			
Radionuclides		Potassium Ferrate Precipitation		

(1) Technology retained in preliminary screening for semivolatiles in the Final TSP were not subjected to final screening

TABLE 4-3B

**SUMMARY OF SOIL/SEDIMENT TREATMENT TECHNOLOGIES
RETAINED AFTER PRELIMINARY SCREENING**

Contaminant Group	Biological Treatments	Physical/Chemical Treatments	Thermal Treatments	Solidification/Stabilization Treatments
PCBs	Slurry Phase Bioreactor	NA	Fluidized Bed Incineration Infrared Thermal Treatment Rotary Kiln Incineration	NA
Metals	NA	NA	NA	NA
Radionuclides	NA	NA	NA	NA

NA - No Additional technologies

TABLE 4-4A
GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
NOT PASSING PRELIMINARY SCREENING

Technology	Reason Rejected from Consideration at This Time
<u>Volatile Organics - Chemical Treatments</u>	
Catalytic Oxidation	Unknown effectiveness and ability to meet cleanup goals Technology not sufficiently developed
Solar Photocatalytic	Unknown potential to meet cleanup goals Technology in experimental stage and not sufficiently developed
<u>Volatile Organics - Biological Treatments</u>	
Aerobic Reductive Dechlorination	Unknown effectiveness, implementability and economics Process in early development stage
Cometabolism Biological Process	Low potential to meet cleanup goal Technology not sufficiently developed
<u>Semivolatile Organics - Physical Treatments</u>	
Carbon Dioxide Extraction	Effective on limited number of constituents Unknown potential to meet cleanup goals
<u>Semivolatile Organics - Chemical Treatments</u>	
Catalytic Oxidation	Unknown potential to meet cleanup goals Technology is in the experimental stage and not sufficiently developed
Solar Photocatalytic	Unknown potential to meet cleanup goals Technology in experimental stage and not sufficiently developed

TABLE 4-4A
GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
NOT PASSING PRELIMINARY SCREENING

Technology	Reason Rejected from Consideration at This Time
<u>Semivolatile Organics - Biological Treatments</u>	
Anaerobic Biological Activated Carbon Process	Low potential to meet cleanup goals Technology not sufficiently developed Additional treatment systems would be required
Anaerobic Reductive Dechlorination	Unknown effectiveness, implementability and economics Process in early development stage
Cometabolism Biological Process	Low potential to meet cleanup goals Technology is in the experimental stage and not sufficiently developed Process is sensitive to influent containment concentrations
In Situ Bioremediation	Low potential to meet cleanup goals Difficult to control and treat broad mixture compounds
<u>PCBs - Physical Treatments</u>	
Solvent Extraction	Low potential to meet cleanup goals at low PCB concentrations Recovered contaminants require treatment
<u>PCBs - Chemical Treatments</u>	
Catalytic Oxidation	Unknown ability to meet cleanup goals Technology is in the experimental stage and not sufficiently developed for PCBs
Solar Photocatalytic	Unknown potential to meet cleanup goals Technology not sufficiently developed for PCBs

TABLE 4-4A
GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
NOT PASSING PRELIMINARY SCREENING

Technology	Reason Rejected from Consideration at This Time
<u>PCBs - Biological Treatments</u> Anaerobic Biological Activated Carbon Process	Unknown potential to meet cleanup goals Additional data needs to be developed to assess effectiveness implementability and O&M requirements
<u>PCBs - Thermal Treatments</u> Solar	Unknown potential to meet cleanup goals Technology not sufficiently developed water matrix with low concentrations of contaminants
<u>Inorganics - Chemical Treatments</u> Catalytic Oxidation	Unknown ability to meet cleanup goals Technology not sufficiently developed for inorganic treatment
<u>Metals - Physical Treatments</u> Hardwicka Binata Bark Adsorption	Unknown ability to meet cleanup goals Technology is in the experimental stage and not sufficiently developed

TABLE 4-4A

**GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
NOT PASSING PRELIMINARY SCREENING**

Technology	Reason Rejected from Consideration at This Time
<u>Metals - Biological Treatments</u>	
Activated Sludge	Questionable potential to meet cleanup goals Low potential for application at RFP Produces large volumes of potentially hazardous waste
Biosorption (Bioaccumulation)	Unknown ability to meet cleanup goals Technology not sufficiently developed Inadequate data has been developed to date on this technology, produces waste sludge
<u>Radionuclides - Physical Treatments</u>	
Alternating Current Electrocoagulation	Unknown potential to meet cleanup goals Technology not sufficiently developed for treatment of radionuclides
Emulsion Liquid Membrane Extraction	Unknown potential to meet cleanup goals Unknown O&M requirements and problems with implementability Inadequate data has been developed on this technology to date
Hollow-Fiber Supported Liquid Membrane	Unknown potential to meet cleanup goals Technology not sufficiently developed
<u>Radionuclides - Biological Treatments</u>	
Enzymatic Microbial Reduction	Unknown potential to meet cleanup goals Unknown O&M requirements and implementability
Biosorption (Bioaccumulation)	Unknown potential to meet cleanup goals Technology not sufficiently developed Produces large volume of radioactive solid waste

TABLE 4-4B

**SOIL/SEDIMENT TREATMENT TECHNOLOGIES
NOT PASSING PRELIMINARY SCREENING**

Technology	Reason Rejected from Consideration at This Time
<u>PCBs - Biological Treatments</u>	
Aerobic Biodegradation	Low potential to meet cleanup goals Technology not sufficiently developed for PCBs
Anaerobic Biological Activated Carbon Process	Unknown potential to meet cleanup goals Technology not sufficiently developed for PCBs
Anaerobic Dechlorination	Unknown ability to meet cleanup goals Technology is in the early development stage and more research is required
<u>PCBs - Physical/Chemical Treatments</u>	
BEST Process	Low potential to meet cleanup goals Production of wastes
CF Systems	Low potential to meet cleanup goals Production of wastes
Organic Extraction Systems	Low potential to meet cleanup goals Technology not sufficiently developed
Fenton's Reagent Decomposition	Fenton's reagent decomposition can produce intermediate products that need treatment
Glycolate Dechlorination	Suitable for high concentrations of PCBs Questionable potential to meet cleanup goals Produces a liquid waste
Surfactant Washing	Unknown potential to meet cleanup goals Technology is still in the experimental stage and not sufficiently developed

TABLE 4-4B

**SOIL/SEDIMENT TREATMENT TECHNOLOGIES
NOT PASSING PRELIMINARY SCREENING**

Technology	Reason Rejected from Consideration at This Time
<u>PCBs - Thermal Treatments</u>	
Solar	Unknown potential to meet cleanup goals Technology not sufficiently developed
Wet Air Oxidation	Questionable ability to meet cleanup goals Suitable for wastes with high organic concentrations Produces offgas and liquid waste
<u>PCBs - Solidification/Stabilization Treatments</u>	
Chemical Stabilization	Unknown potential to meet cleanup goals Technology not sufficiently developed
In Situ Vittrification	Currently not available Withdrawn from market by vendor due to operational problems
Vitrification	Unavailability of commercial capacity
<u>Metals - Solidification/Stabilization Treatments</u>	
In Situ Vitrification	Currently not available Withdrawn from market by vendor due to operational problems
<u>Radionuclides - Solidification/Stabilization Treatments</u>	
In Situ Vitrification	Currently not available Withdrawn from market by vendor due to operational problems
Polymerization - Polyethylene	High O&M requirements Increase in waste volume

TABLE 4-5A

**GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
FINAL TECHNOLOGY SCREENING**

Technology	Additional Data from Laboratory, Bench or Pilot Bench Testing Needed for Selection	Offers Advantages over Other Available Technologies*	Amenable to Testing at Bench/Lab Scale	Test at Bench/Lab Scale	Amenable to Testing at Pilot Scale	Anticipated EPA, State, and/or Community Acceptance	Test** at Pilot Scale
<u>Volatile Organics - Physical Treatments</u>							
In Situ Air Stripping	No	Yes	No	No	Yes	No problems anticipated	No
Aqua Detox (Low Vacuum Steam Stripping)	No	Yes	No	No	Yes	No problems anticipated	No
<u>Volatile Organics - Chemical Treatments</u>							
Ozonation	Yes	Yes	No	No	Yes	No problems anticipated	Yes
Peroxide Oxidation ¹	No ²	Yes	No	No	Yes	No problems anticipated	No
Ultraviolet Oxidation ¹	No ²	Yes	No	No	Yes	No problems anticipated	No
Ultraviolet Photolysis	Yes	Yes	No	No	Yes	No problems anticipated	Yes
<u>Volatile Organics - Biological Treatments</u>							
Aerobic Biological Reactors	Yes	No	Yes	No	Yes	No problems anticipated	No
<u>Semivolatile Organics - Physical Treatments</u>							
Aqua Detox (Low vacuum steam stripping)	No	Yes	No	No	Yes	No problems anticipated	No
Activated Carbon	No	Yes	Yes	No	Yes	No problems anticipated	No
Freeze Crystallization	No	Yes	Yes	No	Yes	No problems anticipated	No
Steam Stripping	No	Yes	Yes	No	Yes	No problems anticipated	No

¹ Subjected to final screening in Final TSP New information from treatability testing warrants reexamination

² OU specific bench test and IRA program at OU1 will provide adequate information

TABLE 4-5A
GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
FINAL TECHNOLOGY SCREENING

Technology	Additional Data from Laboratory, Bench or Pilot Bench Testing Needed for Selection	Offers		Amenable to Testing at Bench/Lab Scale	Test at Bench/Lab Scale	Amenable to Testing at Pilot Scale	Anticipated EPA, State, and/or Community Acceptance	Test** at Pilot Scale
		Advantages over Other Available Technologies*						
<u>Semivolatile Organics - Chemical Treatments</u>								
Catalytic Dechlorination	Yes	No	Yes	Yes	No	Yes	No problems anticipated	No
Gamma Irradiation	Yes	No	No	No	No	Yes	No problems anticipated	No
Ozonation	Yes	Yes	No	No	No	Yes	No problems anticipated	Yes
Peroxide Oxidation	No ¹	Yes	No	No	No	Yes	No problems anticipated	No
Ultraviolet Oxidation	No ¹	Yes	No	No	No	Yes	No problems anticipated	No
Ultraviolet Photolysis	Yes	Yes	No	No	No	Yes	No problems anticipated	Yes
<u>Semivolatile Organics - Biological Treatments</u>								
Contact Stabilization	Yes	No	Yes	Yes	No	Yes	No problems anticipated	No
Extended Aeration	Yes	No	Yes	Yes	No	Yes	No problems anticipated	No
Powdered Activated Carbon	No	Yes	Yes	Yes	No	Yes	No problems anticipated	No
Pure Oxygen Activated Sludge	Yes	No	Yes	Yes	No	Yes	No problems anticipated	No
Submerged Aerobic Fixed Film Reactor	Yes	No	No	No	No	Yes	No problems anticipated	No

¹ OU specific bench test and IRA program at OU1 will provide adequate information

TABLE 4-5A

**GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
FINAL TECHNOLOGY SCREENING**

Technology	Additional Data from Laboratory, Bench or Pilot Bench Testing Needed for Selection	Offers Advantages over Other Available Technologies*	Amenable to Testing at Bench/Lab Scale	Test at Bench/Lab Scale	Amenable to Testing at Pilot Scale	Anticipated EPA, State, and/or Community Acceptance	Test** at Pilot Scale
<u>Semivolatile Organics - Thermal Treatments</u>							
Steam Stripping/Catalytic or Thermal Oxidation	No	Yes	No	No	Yes	Problems expected	No
Supercritical Water Oxidation	Yes	No	No	No	Yes	Problems expected	No
<u>PCBs - Physical Treatments</u>							
Activated Carbon	No	Yes	Yes	No	Yes	No problems anticipated	No
Freeze Crystallization	No	No	Yes	No	Yes	No problems anticipated	No
<u>PCBs - Chemical Treatments</u>							
Ozonation	Yes	Yes	Yes	Yes	Yes	No problems anticipated	No
Peroxide Oxidation	Yes	Yes	Yes	Yes	Yes	No problems anticipated	No
Ultraviolet Oxidation	Yes	Yes	Yes	Yes	Yes	No problems anticipated	No
Ultraviolet Photolysis	Yes	Yes	Yes	Yes	Yes	No problems anticipated	No
<u>PCBs - Biological Treatments</u>							
Powdered Activated Carbon	No	Yes	No	No	Yes	No problems anticipated	No
<u>PCBs Thermal Treatments</u>							
Supercritical Water Oxidation	Yes	No	No	No	Yes	Problems expected	No
<u>Inorganics - Biological Treatments</u>							
Biodenitrification	No	Yes	No	No	Yes	No problems anticipated	No

TABLE 4-5A

**GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
FINAL TECHNOLOGY SCREENING**

Technology	Additional Data from Laboratory, Bench or Pilot Bench Testing Needed for Selection	Offers Advantages over Other Available Technologies*		Amenable to Testing at Bench/Lab Scale	Test at Bench/Lab Scale	Amenable to Testing at Pilot Scale	Anticipated EPA, State, and/or Community Acceptance	Test** at Pilot Scale
<u>Metals - Physical Treatments</u>								
Ultrafiltration	Yes	Yes	Yes	Yes	Yes	Yes	No problems anticipated	No
<u>Radionuclides - Chemical Treatments</u>								
Potassium Ferrate Precipitation (TRU Clear SM)	Yes	Yes	Yes	Yes	Yes	Yes	No problems anticipated	No

* Includes one or more advantages pertaining to cost effectiveness, O&M requirements, or fewer adverse impacts relative to applicable technologies

** Need for pilot testing will be reviewed in future annual reports. Review will be based on results achieved during bench/lab tests (if conducted) and an additional review of site characterization, APARs, technology data, cost of pilot testing and full scale implementation

TABLE 4-5B

**SOIL/SEDIMENT WATER TREATMENT TECHNOLOGIES
FINAL TECHNOLOGY SCREENING**

Technology	Additional Data from Laboratory, Bench or Pilot Bench Testing Needed for Selection	Offers Advantages over Other Available Technologies*		Amenable to Testing at Bench/Lab Scale	Test at Bench/Lab Scale	Amenable to Testing at Pilot Scale	Anticipated EPA, State, and/or Community Acceptance	Test** at Pilot Scale
<u>PCBs - Biological Treatments</u>								
Slurry Phase Bioreactor	Yes	Yes	No	No	No	Yes	No problems anticipated	Yes
<u>PCBS - Thermal Treatments</u>								
Fluidized Bed Incineration	No	Yes	Yes	No	No	Yes	Problems Expected	No
Rotary Kiln Incineration	No	Yes	Yes	No	No	Yes	Problems Expected	No
Infrared Thermal Treatment	Yes	Yes	No	No	No	Yes	Problems Expected	No

* Includes one or more advantages pertaining to cost effectiveness, O&M requirements, or fewer adverse impacts relative to applicable technologies

** Need for pilot testing will be reviewed in annual reports. Review will be based on results achieved during bench/lab tests (if conducted) and an additional review of site characterization, ARARs, technology data, cost of pilot testing and full scale implementation, and EPA/CDH input

TABLE 4-6A

**SUMMARY OF GROUNDWATER/SURFACE WATER TREATMENT TECHNOLOGIES
SELECTED FOR BENCH OR LABORATORY SCALE TREATABILITY STUDIES**

Technology	Contaminant	Appendix B Page Number for Technology Data Sheet
Adsorption ¹	Metals/Radionuclides	B-5
Ion Exchange ¹	Metals/Radionuclides	B-37
Oxidation/Reduction ¹	Metals/Radionuclides	B-39
Ozonation	PCBs	B-63
Peroxide Oxidation	PCBs	B-63
Potassium Ferrate ¹ Precipitation (TRU-Clear™)	Metals/Radionuclides	B-44
Ultrafiltration/ ¹ Microfiltration	Metals/Radionuclides	B-62
Ultraviolet Oxidation	PCBs	B-63
Ultraviolet Photolysis	PCBs	B-63

¹ Technologies previously selected for testing in the Final TSP

TABLE 4-6B

**SUMMARY OF SOIL/SEDIMENT TREATMENT TECHNOLOGIES SELECTED
FOR BENCH OR LABORATORY SCALE TREATABILITY STUDIES**

Technology	Contaminant	Appendix C Page Number for Technology Data Sheet
Magnetic Separation ¹	Radionuclides	C-22
Physical Separation ¹	Metals/Radionuclides	C-25
Soil Washing ¹	Metals/Radionuclides	C-32
Solidification/Stabilization	Metals/Radionuclides	C-37
Polymerization-Epoxy ¹		
Polymerization-Polyester ¹		
Portland Cement ¹		
Masonry Cement ¹		
Gravimetric Physical Separation (TRU Clean TM) ¹	Metals/Radionuclides	C-17

¹ Technologies previously selected for testing in the Final TSP

TABLE 4-7

**TREATMENT TECHNOLOGIES SELECTED FOR PILOT SCALE
TREATABILITY TESTING**

Soil/Sediment Treatment Technology	Estimated Cost of Pilot Study	Appendix B or C Page Number for Technology Data Sheet
Ozonation for VOCs/Semivolatiles	\$250,000	B-59
Slurry Phase Bioreactor for PCBs	\$300,000	C-31
Ultraviolet Photolysis for VOCs/Semivolatiles	\$250,000	B-59

APPENDICES

APPENDIX A
POTENTIAL APPLICABLE OR RELEVANT AND
APPROPRIATE REQUIREMENTS FOR THE SITEWIDE
TREATABILITY STUDIES PROGRAM

TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

FEDERAL STANDARDS										STATE STANDARDS (TBCs)							
Parameter	Type (5)	PQL MDL	RFP	CDH	Method (6)	SDWA	SDWA	SDWA	SDWA	RCRA Subpart F Limit (c)	CDH WQCC Groundwater Quality Standards (d)						
						Maximum Contaminant Level TBCs (a)	Maximum Contaminant Level TBCs (b)	Maximum Contaminant Level Goals TBCs (e)	Maximum Contaminant Level Goal TBCs (f)		Site-Specific (g)						
											Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Agriculture Drinking	Table 3 Agriculture TDS	Table 4 Chronic	Table 5 Chronic	Table 6 Radiocesiums Wagon Wheel Creek
Bicarbonate	A		10 000		E310 1												
Carbonate	A		10 000		E310 1												
Chloride	A		5 000		E325	250 000 *											
Chlorine	A		1 000		E4500												
Fluoride	A		5 000		E340	4 000 2 000 *		4 000				250 000	2 000				
N as Nitrate	A		5 000		E353 1	10 000			10 000				10 000				
N as Nitrate-Nitrite	A		5 000		E353 1		10 000		10 000				10 000				
N as Nitrite	A		5 000		E354 1		1 000		1 000								
Sulfate	A		5 000		E375 4	250 000 *						250 000					
Sulfide	A																
Coliform (total)	B	1			SM9221C	1/100 ml											
Ammonia as N	C	5 000			E350												
Dioxin	D			0 01(9)	d						0 00000022					0 000000013	
Sulfur	E	100 000			E600												
Dissolved Oxygen	FP	500			SM4500												
pH	FP	0 1			E150 1	6 5-8 5 *											
Specific Conductance	FP	1			E120 1								6 5-8 5	6 5-8 5			
Temperature	FP																
Boron	I	5 000			E6010												
Total Dissolved Solids	I	10 000			E160 1	500 000 *									400 000 (1)		
Aluminum	M	200			CT		50 to 200 *										
Antimony	M	60			CT										5 000		
Arsenic	M	10			CT										100		
Arsenic III	M																
Arsenic V	M																
Barium	M	200			CT	1 000	2 000 (e)								1 000		

TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

				FEDERAL STANDARDS				STATE STANDARDS (TBCs)								
Parameter	Type (5)	PQL MDL	Method (6)	SDWA	SDWA	SDWA	SDWA	SDWA	RCRA	CDH WQCC Groundwater Quality Standards (d)						
				Maximum Contaminant Level TBCs (a)	Maximum Contaminant Level TBCs (b)	Maximum Contaminant Level TBCs (c)	Maximum Contaminant Level TBCs (d)	Subpart F Limit (e)	Statewide	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides	
									(d) (7)						Woman Walnut Creek Creek	
Beryllium	M	5	CT	10	5				10			100				
Cadmium	M	5	CT									10				
Calcium	M	5 000	CT													
Cesium	M	1,000	NC													
Chromium	M	10	CT	50	100				50			100				
Chromium III	M	5	SW8467196													
Chromium VI	M	10	E218 5													
Cobalt	M	50	CT									50				
Copper	M	25	CT	1 000 *								1 000				
Cyanide	M	10	CT													
Iron	M	100	CT	300 *					50			300				
Lead	M	5	CT	50												
Lithium	M	100	NC													
Magnesium	M	5000	CT													
Manganese	M	15	CT	50 *												
Mercury	M	0.2	CT	2	2				2			50				
Molybdenum	M	200	NC													
Nickel	M	40	CT													
Potassium	M	5000	CT													
Selenium	M	5	CT	10	50											
Silver	M	10	CT	50	100 *											
Sodium	M	5000	CT													
Strontium	M	200	NC													
Thallium	M	10	CT													
Tin	M	200	NC													
Titanium	M	10	E6010													
Tungsten	M	10	E6010													
Vanadium	M	50	CT													
Zinc	M	20	CT	5 000 *								5 000		100	2 000	

TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

				FEDERAL STANDARDS				STATE STANDARDS (TBCs)									
Parameter	Type (5)	PQL		Method (6)	SDWA	SDWA	SDWA	SDWA	SDWA	RCRA Subpart F Limit (c)	CDH WQCC Groundwater Quality Standards (d)						
		MDL	RFP		Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs	Maximum Contaminant Level Goals TBCs (a)	Maximum Contaminant Level Goals TBCs (b)	Maximum Contaminant Level Goals TBCs (c)		Statewide	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6
													A (d) (7)				
																Woman Walnut Creek Creek	
2,4,5-TP Silvex	P			0.5	d	10	50	10	50	10	50						
2,4-Dichlorophenoxyacetic Acid (2,4-D)	P			1	d	100	70	100	70	100	70						
Acrolein	P			10													
Aldicarb	P			10													
Aldrin	P	0.05		0.1	CP		3 (e)		1 (e)		10						
Bromacil	P										0.002				0.000074		
Carbofuran	P				d		40		40		36						
Chloranil	P																
Chlordane (Alpha)	P	0.5		1	CP		2		0		0.03				0.00046		
Chlordane (Gamma)	P	0.5		1	CP		2		0		0.03				0.00046		
Chlorpyrifos	P				E619												
DDT	P	0.1		0.1	CP						0.1				0.000024		
DDT Metabolite (DDD)	P	0.1			CP												
DDT Metabolite (DDE)	P	0.1		0.1	CP						0.1						
Demeton	P																
Diazinon	P																
Dieldrin	P	0.1		0.1	CP						0.002				0.000071		
Endosulfan I	P	0.05			CP												
Endosulfan II	P	0.1			CP												
Endosulfan sulfate	P	0.1			CP												
Endrin	P	0.1		0.1	CP	0.2				0.2	0.2						
Endrin Aldehyde	P			0.1							0.2						
Endrin Ketone	P	0.1			CP												
Guthion	P																
Heptachlor	P	0.05		0.05	CP	0.4			0		0.008				0.00028		
Heptachlor Epoxide	P	0.05		0.05	CP	0.2			0		0.09						
Hexachlorocyclohexane, Alpha	P	0.05		0.05	CP						0.006				0.0092		

TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

FEDERAL STANDARDS										STATE STANDARDS (TBCs)							
Parameter	Type (5)	PQL MDL		Method (6)	SDWA	SDWA	SDWA	SDWA	SDWA	RCRA Subpart F Limit (c)	CDH WQCC Groundwater Quality Standards (d)					Table 6 Radionuclides Woman Walnut Creek Creek	
		TBCs (a)	Maximum Contaminant Level TBCs (b)		Maximum Contaminant Level Goals TBCs (e)	Maximum Contaminant Level Goal TBCs (f)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture		Table 4 TDS	Table 5 Chronic					
Hexachlorocyclohexane Beta	P	0.05	0.1 (9)	CP											0.0163		
Hexachlorocyclohexane BHC	P	0.05	0.05	CP													
Hexachlorocyclohexane Delta	P	0.05	0.5 (9)	f											0.0123		
Hexachlorocyclohexane Tech	P	0.05	0.05	CP	4	0.2	4.0								0.0186		
Hexachlorocyclohexane, Lindane	P																
Malathion	P																
Methoxychlor	P	0.5	0.5	CP	100	40	100										
Mirex	P																
Permethrin	P																
PCBs	P	0.5	1	CP		0.5									0.0005		
Simazine	P			e													
Toxaphene	P	1	5	CP		3	5.0								0.03	5	
Vaponaite 2	P																
Aroclor 1016	PP	0.5		CP													
Aroclor 1221	PP	0.5		CP													
Aroclor 1232	PP	0.5		CP													
Aroclor 1242	PP	0.5		CP													
Aroclor 1248	PP	0.5		CP													
Aroclor 1254	PP	1		CP													
Aroclor 1260	PP	1		CP													
Atrazine	PP		1 (9)	e		3											
Americium (pCi/l)	R																
Americium 241 (pCi/l)	R	0.01															0.05
Cesium 134 (pCi/l)	R	1															
Cesium 137 (pCi/l)	R	1															80
Gross Alpha (pCi/l)	R	2															7
Gross Beta (pCi/l)	R	4															5
Plutonium (pCi/l)	R				15 (8) 50 (4 mrem/yr)												0.05

TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

				FEDERAL STANDARDS				STATE STANDARDS (TBCs)								
Parameter	Type (5)	PQL MDL	CDH	Method (6)	SDWA	SDWA	SDWA	SDWA	RCRA Subpart F Limit (c)	CDH WQCC Groundwater Quality Standards (d)						
					Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs		Site-Specific (g)						
					(a)	(b)	(c)	(d)		Table A (f) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radiocesium Woods Creek
Plutonium 238+239+240 (pCi/l)	R	0.01								15 (2)						
Radium 226+228 (pCi/l)	R	0.5/1.0 (4)			5					5 (2)						
Strontium 89+90 (pCi/l)	R	1														
Strontium 90 (pCi/l)	R				8 (3)					8 (2)					8	8
Thorium 230+232 (pCi/l)	R									60 (2)						
Tritium (pCi/l)	R									20 000 (2)						500
Uranium 233+234 (pCi/l)	R				20 000 (3)											
Uranium 235 (pCi/l)	R	0.6														
Uranium 238 (pCi/l)	R	0.6														
Uranium (Total) (pCi/l)	R															10
1,2,4,5-Tetrachlorobenzene	SV		10	b						2						
1,2,4-Trichlorobenzene	SV	10		CS												
1,2-Dichlorobenzene (Ortho)	SV	10	1	CS		600		600		620						
1,2-Diphenylhydrazine	SV			b						0.05						
1,3-Dichlorobenzene (Meta)	SV	10	1	CS						620						
1,4-Dichlorobenzene (Para)	SV	10	1	CS				75		75						
2,4,5-Trichlorophenol	SV	50		CS	75					700						
2,4,6-Trichlorophenol	SV	10	50	CS						2				1 2		
2,4-Dichlorophenol	SV	10	50	CS						21						
2,4-Dimethylphenol	SV	10	50	CS						14						
2,4-Dinitrophenol	SV	10		CS												
2,4-Dinitrotoluene	SV	10		CS												
2,6-Dinitrotoluene	SV	10		CS												
2-Chloronaphthalene	SV	10		CS												
2-Chlorophenol	SV	10		CS												
2-Methylnaphthalene	SV	10		CS												
2-Methylphenol	SV	10		CS												
2-Nitroaniline	SV	50		CS												

TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARS/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

				FEDERAL STANDARDS				STATE STANDARDS (TBCs)						
	Types (5)	POL		Method (6)	SDWA Maximum Contaminant Level TBCs (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals TBCs (a)	SDWA Maximum Contaminant Level Goal TBCs (b)	RCRA Subpart F Limit (c)	CDH WQCC Groundwater Quality Standards (d)				
		MDL	RFP							Table A (d) (7)	Site-Specific (g)			
											Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture TDS	Table 4 Chronic
Parameter	(5)													
2-Nitrophenol	SV		10	CS										
3,3-Dichlorobenzidine	SV		20	CS										
3-Nitroaniline	SV		50	CS										
4,6-Dinitro-2-methylphenol	SV		50	CS										
4-Bromophenyl Phenylether	SV		10	CS										
4-Chloroaniline	SV		10	CS										
4-Chlorophenyl Phenyl Ether	SV		10	CS										
4-Chloro-3-methylphenol	SV		10	CS										
4-Methylphenol	SV		10	CS										
4-Nitroaniline	SV		50	CS										
4-Nitrophenol	SV		50	CS										
Acenaphthene	SV		10	CS										
Anthracene	SV		10	CS										
Benazidine	SV			d						0.1			0.00012	
Benzoic Acid	SV		50	CS										
Benzo(a)anthracene	SV		10	CS										
Benzo(a)pyrene	SV		10	CS										
Benzo(b)fluoranthene	SV		10	CS										
Benzo(g,h,i)perylene	SV		10	CS										
Benzo(k)fluoranthene	SV		10	CS										
Benzyl Alcohol	SV		10	CS										
bis(2-Chloroethoxy)methano	SV		10	CS										
bis(2-Chloroethyl)ether	SV		10	CS										
bis(2-Chloroisopropyl)ether	SV		10	CS										
bis(2-Ethylhexyl)phthalate	SV		10	CS									0.0000037	
Butadiene	SV													
Bis(2-ethylhexyl)phthalate	SV		10	CS										
Chlorinated Ethers	SV													
Chlorinated Naphthalenes	SV													

TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

FEDERAL STANDARDS										STATE STANDARDS (TBCs)												
Parameter	Type (5)	PQL MDL		CDH	Method (6)	SDWA	SDWA	SDWA	SDWA	RCRA Subpart F Limit (c)	CDH WQCC Groundwater Quality Standards (d)											
		Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs			Maximum Contaminant Level Goals TBCs (a)	Maximum Contaminant Level Goal TBCs (b)	Table A (d) (7)	Table 1 Human Health		Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides							
		(a)	(b)			(a)	(b)									Watershed	Creek					
Chloroalkyl ethers	SV	10			CS																	
Chlorophenol	SV																					
Chrysene	SV	10			CS																	
Dibenzofuran	SV	10			CS																	
Dibenz(a,h)anthracene	SV	10			CS																	
Dichlorobenzene	SV																					
Dichlorobenzidine	SV	20		10(9)	CS																	
Diethylphthalate	SV	10			CS																	
Dimethylphthalate	SV	10			CS																	
Di-n-butylphthalate	SV	10			CS																	
Di-n-octylphthalate	SV	10			CS																	
Ethylene Glycol	SV				d																	
Fluoranthene	SV	10			CS																	
Fluorene	SV	10			CS																	
Formaldehyde	SV																					
Halocarbon	SV																					
Hexachlorobenzene	SV	10		10	CS																	
Hexachlorobutadiene	SV	10		10	CS																	
Hexachlorocyclopentadiene	SV	10		10	CS																	
Hexachloroethane	SV	10		10	CS																	
Hydrazine	SV																					
Indeno(1,2,3-cd)pyrene	SV	10			CS																	
Isophorone	SV	10			CS																	
Naphthalene	SV	10		10	CS																	
Nitrobenzene	SV	10		10	CS																	
Nitrophenols	SV																					
Nitrosamines	SV																					
Nitrosodibutylamine	SV				b																	
Nitrosodimethylamine	SV				b																	

TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

				FEDERAL STANDARDS					STATE STANDARDS (TBCs)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Parameter	Type	PQL MDL	CDH	Method	SDWA	SDWA	SDWA	SDWA	SDWA	RCRA Subpart F Limit	CDH WQCC Groundwater Quality Standards (d)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
					Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs	Maximum Contaminant Level TBCs		Site-Specific (g)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
					(a)	(b)	(c)	(d)	Table A (d) (7)		Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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TABLE A-1 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
GROUNDWATER QUALITY STANDARDS (ug/l)

FEDERAL STANDARDS										STATE STANDARDS (TBCs)							
Parameter	Type (5)	PQL		CDH	Method (6)	SDWA	SDWA	SDWA	SDWA	RCRA Subpart F Limit (c)	CDH WQCC Groundwater Quality Standards (d)						
		Maximum Contaminant Level TBCs (a)	Maximum Contaminant Level TBCs (b)			Maximum Contaminant Level Goals TBCs (c)	Maximum Contaminant Level Goal TBCs (b)	Table A (d) (7)	Site-Specific (g)								
									Table 1 Human Health		Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides		
		RFP	MDL													Women	Walnut Creek
Acrylonitrile	V	5		15(9)	c	5		0							0.058		
Benzene	V	5		1	CV					1							
Bromodichloromethane	V	5		1	CV					0.3							
Bromoform	V	5		1	CV					4							
Bromomethane	V	10			CV												
Carbon Disulfide	V	5			CV												
Carbon Tetrachloride	V	5		1	CV	5		0		0.3							
Chlorinated Benzenes	V	10			CV/CS												
Chlorobenzene	V	5		1	CV/CS	100			100	100							
Chloroethane	V	10			CV												
Chloroform	V	5		1	CV	Tot THM <100**				6					0.19		
Chloromethane	V	10			CV												
Dibromochloromethane	V	5		1	CV					14							
Dichloroethanes	V																
Ethyl Benzene	V	5		1	CV	700	0.05		700	680							
Ethylene Dibromide	V				d	0.05			0	0.0004							
Ethylene Oxide	V																
Halomethanes	V			1 (9)		100				100					0.19		
Methylene Chloride	V	5			CV												
Pyrene	V	10			CS												
Styrene	V	5			CV	100			100								
Tetrachloroethanes	V	5			CV												
Tetrachloroethene	V	5		1	CV	5		0	0	5					0.8		
Toluene	V	5		1	CV	1 000		1 000	1 000	1 000							
Trichloroethanes	V	5			CV												
Trichloroethene	V	5		1	CV	5		0		5							
Vinyl Acetate	V	10			CV												
Xylenes (total)	V	5			CV	10 000		10 000	10 000								

EXPLANATION OF TABLE

* = secondary maximum contaminant level TBCs
 ** = total trihalomethanes chloroform bromoform, bromodichloromethane dibromochloromethane

CDH = Colorado Department of Health
 CLP = Contract Laboratory Program
 EPA = Environmental Protection Agency
 MDL = Minimum Detection Limit for radionuclides (pCi/l)
 pCi/l = picocuries per liter
 PCB = polychlorinated biphenyl
 PQL = Practical Quantitation Limit
 RCRA = Resources Conservation and Recovery Act
 RFP = Rocky Flats Plant
 SDWA = Safe Drinking Water Act
 TAL = Target Analyte List
 THM = Total Trihalomethanes
 TIC = Tentatively Identified Compound
 ug/l = micrograms per liter
 VOA = Volatile Organic Analysis
 WQCC = Water Quality Control Commission

- (1) TDS standard - see Table 4 in (d) standard is 400 mg/l or 1.25 times the background level whichever is least restrictive
- (2) radionuclide standards - see sec 3.11.5(c)(2) in (d)
- (3) If both strontium-90 and tritium are present the sum of their annual dose equivalents to bone marrow shall not exceed 4 mrem/yr
- (4) MDL for Radium 226 is 0.5 MDL for radium 228 is 1
- (5) type abbreviations are A=anion B=bacteria C=cation D=dioxin E=element FP=field parameter I=indicator M=metal P=pesticide PP=pesticide/PCB
 R=radionuclide SV=semi-volatile V=volatile
- (6) method abbreviations are CT=CLP-TAL NC=non-CLP CV=CLP-VOA CS=CLP-SEMI EP=EPA-PEST CP=CLP-PEST E=EPA, a = detected as total in CV, b = detected as TICs in CS c = detected as TIC in CV
 d = not routinely monitored e = monitored in discharge ponds f = mixture-individual isomers detected
- (7) Where standard is below (more stringent than) PQL (CDH), PQL is standard
- (8) Value for gross alpha excludes uranium
- (9) Value is CDH detection level (PQL not available)
- (a) EPA National Primary and Secondary Drinking Water Regulations 40 CFR 141 and 40 CFR 143 (as of 5/1/90)
- (b) EPA National Primary and Secondary Drinking Water Regulations 40 CFR Parts 141 142 143 Final Rule Effective July 30 1992 (56 Federal Register 3526 1/30/1991)
- (c) NCP 40 CFR 300, NCP Preamble 55 FR 8764 CERCLA Compliance with Other Laws Manual EPA/540/G-89/006 August 1988 40 CFR 264.94
- (d) CDH/Water Quality Control Commission, The Basic Standards for Ground Water 3.11.0 (5 CCR 1002-8) 1/5/1987 amended 11/30/1991 statewide radioactive standards listed in 3.11.5(c)(2)
- (e) EPA National Primary and Secondary Drinking Water Regulations 40 CFR Parts 141 142 143 Final Rule Effective January 1 1993 (56 FR 30266 7/1/1991)
- (f) EPA Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper 40 CFR 141 and 142 (56 FR 26460 6/7/91) effective 12/7/92
- (g) CDH/Water Quality Control Commission Classifications and Water Quality Standards for Ground Water 3.12.0 (9/19/1991)

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Parameter	Type (7)	PQL		Method (8)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals TBCs (b)	CWA AWQC for Protection of Aquatic Life (c)		CWA AWQC for Protection of Human Health (c)	
		MDL	RFP						Acute Value	Chronic Value	Water and Fish Ingestion	Fish Consumption Only
Bicarbonate	A		10 000	E310 1								
Carbonate	A		10 000	E310 1								
Chloride	A		5 000	E325	250 000*				860,000(e) 19	230 000(e) 11		4 000
Chlorine	A		1 000	E4500								
Fluoride	A		5 000	E340	4 000 2 000*		4 000					
N as Nitrate	A		5 000	E353 1	10 000	10 000		10 000			10,000	
N as Nitrate+Nitrite	A		5 000	E353 1				10 000				
N as Nitrite	A		5 000	E354 1		1 000		1 000				
Sulfate	A		5,000	E375 4	250 000*							
Sulfide	A											
Coliform (Fecal)	B		1	SM9221C	1/100 ml							
Ammonia as N	C		5 000	E350					Criteria are pH and temperature 0 01	0 00001	dependent - see criteria document 0 000000013	0 000000014
Dioxin	D			d								
Sulfur	E		100 000	E600					5 000	6 5-9		
Dissolved Oxygen	FP		500	SM4500								
pH	FP		0 1	E150 1	6 5-8 5 *							
Specific Conductance	FP		1	E120 1					SS	SS		
Temperature	FP								SS	SS		
Boron	I		5 000	E6010					SS	SS	250 000	
Total Dissolved Solids	I		10 000	E160 1	500 000*							
Aluminum	M		200	CT		50 to 200*			750	87		
Antimony	M		60	CT					9 000	1 600	146	45 000
Arsenic	M		10	CT	50						0 0022	0 0175
Arsenic III	M								360	190		
Arsenic V	M								850	48		
Barium	M		200	CT	1 000	2 000 (f)		2 000 (f)			1 000	
Beryllium	M		5	CT				5	130	5 3	0068**	117**
Cadmium	M		5	CT	10	5		5	3 9 (3)	1 1 (3)	10	
Calcium	M		5 000	CT								

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Parameter	Type (7)	PQL		Method (8)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (c)	SDWA Maximum Contaminant Level TBCs (b)	CWA AWQC for Protection of Aquatic Life (c)	CWA AWQC for Protection of Human Health (c)			
		MDL	RFP							Acute Value	Chronic Value	Water and Fish Ingestion	Fish Consumption Only
Cesium	M		1 000	NC	50	100		100				3 433 000	
Chloronium	M		10	CT							170 000		
Chromium III	M		5	SW846/196									
Chromium VI	M		10	E218 5							50		
Cobalt	M		50	CT									
Copper	M		25	CT	1 000*		1 300 (g)	18 (3)	22	12 (3)	200		
Cyanide	M		10	CT						5 2	300		
Iron	M		100	CT	300 *		0 (g)	82 (3)		1 000	50		
Lead	M		5	CT	50					3 2 (3)			
Lithium	M		100	NC									
Magnesium	M		5000	CT	50 *						50	100	
Manganese	M		15	CT	2	2			2 4	0 012	0 144	0 146	
Mercury	M		0 2	CT									
Molybdenum	M		200	NC									
Nickel	M		40	CT					1 400 (3)	160 (3)	13 4	100	
Potassium	M		5000	CT									
Selenium	M		5	CT	10	50	50	50	20 (d)	5 (d)	10		
Silver	M		10	CT	50	100 *			4 1 (3)	0 12	50		
Sodium	M		5000	CT									
Strontium	M		200	NC									
Thallium	M		10	CT									
Tin	M		200	NC					1 400 (1)	40 (1)	13	48	
Titanium	M		10	E6010									
Tungsten	M		10	E6010									
Vanadium	M		50	CT									
Zinc	M		20	CT	5 000 *				120 (3)	110 (3)			
2 4 5-TP Silver	P			0 5 d	10	50	50						
2 4-Dichlorophenoxyacetic Acid (2 4-D)	P			1 d	100	70	70						
Acroline	P			10					68(1)	21(1)	320	780	
Aldicarb	P			10		3 (f)	1 (f)						

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARS/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Pesticide	Type (7)	PQL MDL		Method (8)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level TBCs (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c)	
		RFP	CDH (8)								Fish Ingestion	Fish Consumption Only
Aldrin	P	0.05	0.1	CP					3.0		0.00074	0.00079
Bromacil	P			d		40		40				
Carbofuran	P											
Chloranil	P	0.5	1	CP		2		0	2.4	0.0043	0.00046	0.00048
Chlordane (Alpha)	P	0.5	1	CP		2		0	2.4	0.0043	0.00046	0.00048
Chlordane (Gamma)	P			E619								
Chlorpyrifos	P	0.1	0.1	CP					0.063	0.041		
DDT	P	0.1	0.1	CP					1.1	0.011	0.00024	0.00024
DDT metabolite (DDD)	P	0.1	0.1	CP					0.06			
DDT metabolite (DDE)	P	0.1	0.1	CP					1.050	0.1		
Demeton	P		1									
Diazinon	P											
Dieldrin	P	0.1	0.1	CP					2.5	0.0019	0.00007	0.00076
Endosulfan I	P	0.05	0.1	CP					0.22	0.056	74	159
Endosulfan II	P	0.1	0.1	CP								
Endosulfan Sulfate	P	0.1	0.1	CP								
Endrin	P	0.1	0.1	CP	0.2				0.18	0.0023	1	
Endrin Aldehyde	P		0.1									
Endrin Ketone	P	0.1		CP								
Guthion	P		1.5									
Heptachlor	P	0.05	0.05	CP		0.4		0	0.52	0.01	0.00028	0.00029
Heptachlor Epoxide	P	0.05	0.05	CP		0.2		0				
Hexachlorocyclohexane Alpha	P	0.05	0.05	CP							0.0092	0.031
Hexachlorocyclohexane Beta	P	0.05	0.05	CP							0.0163	0.0547
Hexachlorocyclohexane BHC	P	0.05	0.05	CP								
Hexachlorocyclohexane Delta	P	0.05	0.05	CP								
Hexachlorocyclohexane Technical	P	0.05	0.2	f								
Hexachlorocyclohexane Gamma	P	0.05	0.05	CP	4	0.2		0.2	2.0	0.08	0.0123	0.0414
Malathion	P	0.05	0.2									
Methoxychlor	P	0.5	0.5	CP	100	40		40			100	
Mirex	P		0.1									

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Parameter	Type (7)	PQL		Method (8)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (c)	SDWA Maximum Contaminant Level Goals (d)	CWA AWQC for Protection of Aquatic Life (c)		CWA AWQC for Protection of Human Health (c)	
		MDL	RFP						Acute Value	Chronic Value	Water and Fish Ingestion	Fish Consumption Only
Parathion	P		0.5	1		0.5			0.065	0.013		
PCBs	P								2.0	0.014		0.00079**
Simazine	P			e								
Toxaphene	P		1	5		3			0.73	0.0002		0.00073**
Vapontol 2	P											
Aroclor 1016	PP		0.5									
Aroclor 1221	PP		0.5									
Aroclor 1232	PP		0.5									
Aroclor 1242	PP		0.5									
Aroclor 1248	PP		0.5									
Aroclor 1254	PP		1									
Aroclor 1260	PP		1									
Atrazine	PP			e		3						
Americium (pCi/l)	R											
Americium 241 (pCi/l)	R		0.01									
Cesium 134 (pCi/l)	R		1									
Cesium 137 (pCi/l)	R		1									
Gross Alpha (pCi/l)	R		2		15 (10)							15
Gross Beta (pCi/l)	R		4		50 (4 mrem/yr)							
Plutonium (pCi/l)	R											
Plutonium 238+239+240 (pCi/l)	R		0.01									
Radium 226+228 (pCi/l)	R		0.5/0.1 (9)									
Strontium 89+90 (pCi/l)	R		1		5							5
Strontium 90 (pCi/l)	R											
Thorium 230+232 (pCi/l)	R				8 (6)							8
Tritium (pCi/l)	R				20 000 (6)							
Uranium 233+234 (pCi/l)	R											
Uranium 235 (pCi/l)	R		0.6									
Uranium 238 (pCi/l)	R		0.6									
Uranium (total) (pCi/l)	R											

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARS/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Parameter	Type (7)	PQL		Method (8)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (c)	SDWA Maximum Contaminant Level Goals TBCs (b)	CWA AWQC for Protection of Aquatic Life (c)		CWA AWQC for Protection of Human Health (c)	
		MDL	RFP						Acute Value	Chronic Value	Fish Ingestion	Fish Consumption Only
1,2,4,5-Tetrachlorobenzene	SV		10	b							38	48
1,2,4-Trichlorobenzene	SV	10		CS								
1,2-Dichlorobenzene (Ortho)	SV	10	10	CS				600	270 (1)			
1,2-Diphenylhydrazine	SV			b								
1,3-Dichlorobenzene (Meta)	SV	10	1	CS								
1,4-Dichlorobenzene (Para)	SV	10	1	CS								
2,4,5-Trichlorophenol	SV	50		CS	75		75					
2,4,6-Trichlorophenol	SV	10	50	CS							2 800	
2,4-Dichlorophenol	SV	10	50	CS					970 (1)		1 2 **	3 6 **
2,4-Dimethylphenol	SV	10	50	CS					2,020 (1)	365 (1)	3 090	
2,4-Dinitrophenol	SV	50	50	CS					2 120 (1)			
2,6-Dinitrotoluene	SV	10	10	CS							0 11 **	9 1 **
2-Chloronaphthalene	SV	10	10	CS					330 (1)	230 (1)	70	14 300
2-Chlorophenol	SV	10	50	CS					4 360 (1)	2,000 (1)		
2-Methylnaphthalene	SV	10		CS								
2-Methylphenol	SV	10		CS								
2-Nitroaniline	SV	50		CS								
2-Nitrophenol	SV	10		CS								
3,3'-Dichlorobenzidine	SV	20	10	CS							0 01	0 02
3-Nitroaniline	SV	50		CS								
4,6-Dinitro-2-methylphenol	SV	50	50	CS								
4-Bromophenyl Phenylether	SV	10		CS								
4-Chloroaniline	SV	10		CS								
4-Chlorophenyl Phenyl Ether	SV	10		CS					30 (1)			
4-Chloro-3-methylphenol	SV	10	50	CS								
4-Methylphenol	SV	10		CS								
4-Nitroaniline	SV	50		CS					230 (1)	150 (1)		
4-Nitrophenol	SV	50		CS					1 700 (1)	520 (1)		
Acenaphthene	SV	10	10	CS								

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Parameter	Type (7)	PQL MDL		Method (8)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (c)	CWA AWQC for Protection of Aquatic Life (e)		CWA AWQC for Protection of Human Health (e)	
		RFP	CDH (6)					Acute Value	Chronic Value	Fish Ingestion	Water and Fish Consumption Only
Anthracene	SV	10	1	CS				2,500		0 00012	0 00053
Benidine	SV	50	1	d							
Benzoic Acid	SV	10	10	CS							
Benzo(a)anthracene	SV	10	10	CS							
Benzo(a)pyrene	SV	10	10	CS							
Benzo(b)fluoranthene	SV	10	10	CS							
Benzo(g,h,i)perylene	SV	10	10	CS							
Benzo(k)fluoranthene	SV	10	10	CS							
Benzyl Alcohol	SV	10		CS							
bis(2-Chloroethoxy)methane	SV	10		CS							
bis(2-Chloroethoxy)ether	SV	10	10	CS					0 03**	0 03**	1 36 **
bis(2-Chloroisopropyl)ether	SV	10	10	CS					34 7	34 7	4 360
bis(2-Ethylhexyl)phthalate	SV	10	10	CS					15 000	15 000	50 000
Butadiene	SV										
Butylbenzylphthalate	SV	10	10	CS							
Chlorinated Ethers	SV										
Chlorinated Naphthalenes	SV							1 600 (1)			
Chloroalkyl ethers	SV	10		CS				238 000 (1)			
Chlorophenol	SV		50								
Chrysene	SV	10	10	CS							
Dibenzofuran	SV	10	10	CS							
Dibenz(a,h)anthracene	SV	10	10	CS							
Dichlorobenzene	SV		1								
Dichlorobenzidine	SV	20	10	CS				1 120 (1)	763 (1)	400	2 600
Diethylphthalate	SV	10	10	CS						0 01	0 02
Dimethylphthalate	SV	10	10	CS						350 000	1 800 000
Di-n-butylphthalate	SV	10	10	CS						313 000	2 900 000
Di-n-octylphthalate	SV	10		CS							
Ethylene Glycol	SV			d							
Fluoranthene	SV	10	10	CS				3 980 (1)		42	54
Fluorene	SV	10	10	CS							

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Parameter	Type (7)	PQL MDL		Method (8)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals TBCs (b)	CWA AWQC for Protection of Aquatic Life (c)		CWA AWQC for Protection of Human Health (e)	
		RFP	CDH						Acute Value	Chronic Value	Water and Fish Ingestion	Fish Consumption Only
Formaldehyde	SV								380 (1)	122 (1)	0.00072**	0.00074**
Halothane	SV	10	10	CS								
Hexachlorobenzene	SV	10	10	CS					90 (1)	9.3 (1)	0.45**	50 **
Hexachlorobutadiene	SV	10	10	CS					7 (1)	5.2 (1)	206	
Hexachlorocyclopentadiene	SV	10	10	CS					980 (1)	540 (1)	1.9	8.74
Hydrazine	SV											
Isodao (1,2,3-cd)pyrene	SV	10	10	CS					117 000 (1)		5.200	520 000
Isophorone	SV	10	10	CS					2 300 (1)	620 (1)	19 800	
Naphthalene	SV	10	10	CS					27 000 (1)			
Nitrobenzene	SV	10	10	CS					230 (1)	150 (1)		
Nitrophenols	SV								5 850 (1)			
Nitroamines	SV											
Nitrosodimethylamine	SV		10	b							0.0064	0.587
Nitrosodimethylamine	SV		10	b							0.0008	1.24
Nitrosodimethylamine	SV		10	b							0.0014	16
Nitrosodimethylamine	SV		10	b							0.016	91.9
Nitrosopyrrolidone	SV		10	b							4.9 **	16.1 **
N-Nitrosodiphenylamine	SV	10	10	b								
N-Nitroso-di-n-propylamine	SV	10	10	b								
Perchlorinated Ethanes	SV								7 240 (1)	1 100 (1)	74	85
Perchlorinated Ethanes	SV		10	b				0 (f)				
Perchlorinated Ethanes	SV	50	50	CS					20 (4)	13 (4)	1.010	
Perchlorinated Ethanes	SV	10	10	CS					10 200 (1)	2 560 (1)	3 500	
Phenanthrene	SV	10	50	CS					940 (1)	3 (1)		
Phenol	SV											
Phthalate Esters	SV		10	b							0.0028**	0.0311**
Polynuclear Aromatic Hydrocarbons	SV		2	CV							2 **	525 **
Vinyl Chloride	SV	10										
1,1,1-Trichloroethane	V	5	1	CV	200						18 400	1 030 000
1,1,2-Trichloroethane	V	5	1	CV							0.17**	10.7 **
1,1,2-Trichloroethane	V	5	1	CV							0.6**	41.8 **

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Parameter	Type (7)	PQL		Method (8)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c)	CWA AWQC for Protection of Human Health (c)		Fish Consumption Only
		MDL	RFP							Chronic Value	Acute Value	
1,1-Dichloroethane	V	5		CV	7				118 000	20 000	0.94**	243 **
1,1-Dichloroethene	V	5	1	CV	5		7					
1,2-Dichloroethane	V	5	1	CV		70	0	70				
1,2-Dichloroethene (cis)	V	5	1	a								
1,2-Dichloroethene (total)	V	5	1	CV								
1,2-Dichloroethene (trans)	V	5	1	a		100		100				
1,2-Dichloropropane	V	5	1	CV		5		0	23 000	5 700		
1,3-Dichloropropane (cis)	V	5	1	CV					6 060	244 (1)	87	14 100
1,3-Dichloropropane (trans)	V	5	1	CV					6 060	244 (1)	87	14 100
2-Butanone	V	10		CV								
2-Hexanone	V	10		CV								
4-Methyl-2-pentanone	V	10		CV								
Acetone	V	10		CV								
Acrylonitrile	V	5	5	c	5		0		7 500	2,600	0.058	0.65
Benzene	V	5	1	CV					5 300		0.66**	40 **
Bromodichloromethane	V	5	1	CV								
Bromoform	V	5	1	CV								
Bromomethane	V	10	1	CV								
Carbon Disulfide	V	5	1	CV								
Carbon Tetrachloride	V	5	1	CV	5				35 200 (1)	50 (1)	0.4**	6.94 **
Chlorinated Benzenes	V	10		CV/CS					250 (1)			
Chlorobenzene	V	5	1	CV/CS								
Chloroethane	V	10	1	CV		100		100				
Chloroform	V	5	1	CV	Tot THM<100 (2)				28 900 (1)	1 240 (1)	0.19 **	15.7 **
Chloromethane	V	5	1	CV								
Dibromochloromethane	V	10	1	CV								
Dichloroethane	V	5	1	CV								
Diethyl Benzene	V	5	1	CV					11 600 (1)		0.033**	1.85 **
Ethylene Dibromide	V	5	1	CV		700		700	32 000 (1)		1.400	3 280
Ethylene Oxide	V			d		0.05		0				
Halomethanes	V				100				11 000 (1)		0.19**	15.7 **

TABLE A-2 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
FEDERAL SURFACE WATER QUALITY STANDARDS (ug/l)

Parameter	Type	PQL		Method	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level TBCs (b)	SDWA Maximum Contaminant Level Goals (c)	SDWA Maximum Contaminant Level Goals (d)	CWA AWQC for Protection of Aquatic Life (e)	CWA AWQC for Protection of Human Health (f)	CWA AWQC for Protection of Human Health (g)
		MDL	RFP								
Methylene Chloride	V	5	1	CV							
Pyrene	V	10	10	CS							
Styrene	V	5	5	CV		100					
Tetrachloroethanes	V	5	1	CV		5			9 320 (1)		
Tetrachloroethene	V	5	1	CV		1 000			5 280 (1)	840 (1)	0 80**
Toluene	V	5	1	CV		1 000			17 500 (1)	14 300	424 000
Trichloroethanes	V	5	1	CV					18 000 (1)		
Trichloroethene	V	5	1	CV	5				45 000 (1)	21 900 (1)	2 7 **
Vinyl Acetate	V	10	1	CV				0			80 7 **
Xylenes (total)	V	5	5	CV		10 000		10 000			

EXPLANATION OF TABLE

* = secondary maximum contaminant level TBCs

** = Human health criteria for carcinogens reported for three risk levels Value presented is the 10-5 risk level

AWQC = Ambient Water Quality Criteria
 CLP = Contract Laboratory Program
 CWA = Clean Water Act
 EPA = Environmental Protection Agency
 MDL = Minimum Detection Limit for radionuclides (pCi/l)
 pCi/l = picocuries per liter
 PCB = polychlorinated biphenyl
 PQL = Practical Quantitation Level
 SDWA = Safe Drinking Water Act
 SS = Species Specific
 TAL = Target Analyte List
 THM = Total Trihalomethanes
 TIC = Tentatively Identified Compound
 ug/l = micrograms per liter
 VOA = Volatile Organic Analysis

(1) criteria not developed, value presented is lowest observed effects level (LOEL)
 (2) total trihalomethanes chloroform bromoform, bromodichloromethane, dibromochloromethane

(3) hardness dependent criteria

(4) pH dependent criteria (7.8 pH used)

(5) standard is not adequately protective when chloride is associated with potassium calcium or magnesium rather than sodium

(6) if both strontium-90 and tritium are present, the sum of their annual dose equivalents to bone marrow shall not exceed 4 mrem/yr

(7) type abbreviations are A=anion B=bacteria C=cation D=dioxin E=element I=indicator FP=field parameter M=metal P=pesticide PP=pesticide/PCB, R=radionuclide SV=semi-volatile, V=volatile

(8) method abbreviations are CT=CLP-TAL, NC=non-CLP CV=CLP-VOA CS=CLP-SEMI EP=EPA-PEST CP=CLP-PEST E=EPA, a = detected as total in CV b = detected as TIC in CS

c = detected as TIC in CV d = not routinely monitored e = monitored in discharge ponds f = mixture-individual isomers detected

(9) MDL for radium 226 is 0.5 MDL for radium 228 is 1.0

(10) Value for gross alpha excludes uranium

(a) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR 141 and 40 CFR 143 (as of May 1990) Segment 4 MCLs are ARAR Segment 5 MCLs are TBC all MCLGs are TBC
 (b) EPA National Primary and Secondary Drinking Water Regulations 40 CFR Parts 141 142 and 143 Final Rule effective July 30 1992 (56 Federal Register 3526 1/30/1991)
 (c) EPA, Quality Criteria for Protection of Aquatic Life, 1986
 (d) EPA, National Ambient Water Quality Criteria for Selenium - 1987
 (e) EPA, National Ambient Water Quality Criteria for Chloride - 1988
 (f) EPA National Primary and Secondary Drinking Water Regulations 40 CFR Parts 141 142 and 143 Final Rule (56 FR 30266 7/1/1991) effective 1/1/1993
 (g) EPA Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper 40 CFR 141 and 142 (56 FR 26460 6/7/1991) effective 12/7/91

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)													Basin Standards (b)	
Parameter	Type (5)	PQL		Method (6)	Human Health Carcinogens/Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I II III (1)				Organics (7)	
		MDL	RFP		Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricultural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
Bicarbonate	A	10 000	E310 1											
Carbonate	A	10 000	E310 1											
Chloride	A *	5 000	E325											
Chlorine	A	1 000	E4500						19	11				
Fluoride	A	5 000	E340											
N as Nitrate	A	5 000	E353 1											
N as Nitrate+Nitrite	A	5 000	E353 1											
N as Nitrite	A	5 000	E354 1						SS	SS				
Sulfate	A	5 000	E375 4							2				
Sulfide	A													
Coliform (Fecal)	B	I	SM9221C											
Ammonia as N	C	5 000	E350						620	60				
Dioxin	D		d		0 00000022	0 000000013	0 01	0 00001						
Sulfur	E	100 000	E600											
Dissolved Oxygen	FP	500	SM4500						5 000	5 000	3 000	3 000		
pH	FP	0 1	E150 1						6 5-9 0	6 5-9 0				
Specific Conductance	FP	I	E120 1											
Temperature	FP								30 degrees	30 degrees	750			
Boron	I	5 000	E6010											
Total Dissolved Solids	I	10 000	E160 1											
Aluminum	M	200	CT						750	87				
Antimony	M	60	CT										14	
Arsenic	M	10	CT						360	150	100	50		
Arsenic III	M													
Arsenic V	M													
Barium	M	200	CT										1 000	
Beryllium	M	5	CT								100		0 0076	

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)															Basin Standards (b)	
Parameter	Type (5)	PQL MDL RFP	CDH	Method (6)	Human Health Carcinogens/ Noncarcinogens (2) (8)	Tables I,II,III (1)					Organics (7)	Aquatic Water Life	Water Supply			
						Aquatic Life (8)		Aquatic Life		Agricul- tural Standard (3)				Domestic Water Supply (4)		
						Acute Value	Chronic Value	Acute Value	Chronic Value							
															Water Supply	Water and Fish
Cadmium	M	5		CT			TVS	TVS	TVS	10	10					
Calcium	M	5 000		CT												
Cesium	M	1 000		NC												
Chromium	M	10		CT												
Chromium III	M	5		SW8467196												
Chromium VI	M	10		E218 5												
Cobalt	M	50		CT												
Copper	M	25		CT												
Cyanide	M	10		CT												
Iron	M	100		CT												
Lead	M	5		CT												
Lithium	M	100		NC												
Magnesium	M	5000		CT												
Manganese	M	15		CT												
Mercury	M	0.2		CT												
Molybdenum	M	200		NC												
Nickel	M	40		CT												
Potassium	M	5000		CT												
Selenium	M	5		CT												
Silver	M	10		CT												
Sodium	M	5000		CT												
Strontium	M	200		NC												
Thallium	M	10		CT												
Tin	M	200		NC												
Titanium	M	10		E6010												
Tungsten	M	10		E6010												
Vanadium	M	50		CT												
Zinc	M	20		CT												
2.4.5-TP Silver	P		0.5	d												
						50										

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)													Basin Standards (b)				
Parameter	Type (5)	PQL MDL		CDH	Method (6)	Human Health			Aquatic Life (8)		Tables I II III (1)				Organics (7)		
		RFP	MDL			Carcinogens/ Noncarcinogens (2) (8)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricultural Standard (3)	Domestic Water Supply (4)	Aquatic Life		
2,4-D	P			1	d	70		68	21								
Acrolein	P			10			320										
Aldicarb	P			10		10											
Aldrin	P	0.05		0.1	CP	0.002 (8)	0.00013	1.5								0.003	
Bromacil	P																
Carbofuran	P				d	36											
Chloranil	P				E619												
Chlordane (Alpha)	P	0.5		1	CP	0.03 (8)		1.2	0.0043								
Chlordane (Gamma)	P	0.5		1	CP	0.03 (8)	0.00058	1.2	0.0043								
Chlorpyrifos	P			0.1				0.083	0.041								
DDT	P	0.1		0.1	CP	0.1	0.00059	0.55	0.001							0.001	
DDT Metabolite (DDD)	P	0.1		0.1	CP		0.0008	0.6								0.001	
DDT Metabolite (DDE)	P	0.1		0.1	CP	0.1	0.00059	1.050								0.001	
Demeton	P			1					0.1							0.1	
Diazinon	P																
Dieldrin	P	0.1		0.1	CP	0.002	0.00014	1.3	0.0019							0.003	
Endosulfan I	P	0.05		0.1	CP		0.93	0.11	0.056							0.003	
Endosulfan II	P	0.1		0.1	CP												
Endosulfan Sulfate	P	0.1		0.1	CP		0.93										
Endrin	P	0.1		0.1	CP	0.2		0.09	0.0023							0.004	
Endrin Aldehyde	P			0.1		0.2	0.2										
Endrin Ketone	P	0.1			CP												
Guthion	P			1.5													
Heptachlor	P	0.05		0.05	CP	0.008	0.00021	0.26	0.0038							0.01	
Heptachlor Epoxide	P	0.05		0.05	CP	0.09	0.0001	0.26	0.0038							0.001	
Hexachlorocyclohexane Alpha	P	0.05		0.05	CP	0.006		0.0039									0.2
Hexachlorocyclohexane Beta	P	0.05		0.05	CP												
Hexachlorocyclohexane BHC	P	0.05		0.05	CP		0.014	100									
Hexachlorocyclohexane Delta	P	0.05		0.05													
Hexachlorocyclohexane Tech	P	0.05		0.2	f		0.012										

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)																	Basin Standards (b)	
Parameter	Type (5)	PQL		Method (6)	Human Health			Aquatic Life (8)		Tables I, II III (1)				Organics (7)				
		MDL	RFP		Carcinogens/Noncarcinogens (2) (8)	Water Supply	Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricultural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply			
Hexachlorocyclohexane, Lindane	P	0.05	0.05	CP	0.2	0.019	1.0	0.08					0.01	4.0				
Malathion	P		0.2					0.1					0.1					
Methoxychlor	P	0.5	0.5	CP	40			0.03					0.03	100				
Mirex	P		0.1					0.001					0.001					
Parathion	P												0.04					
PCBs	P	0.5	1	CP	0.005	0.000044	2.0	0.014					0.001					
Simazine	P			e														
Toxaphene	P	1	5	CP	0.03	0.00073	0.73	0.0002					0.005	5.0				
Vapontite 2	P																	
Aroclor 1016	PP	0.5		CP														
Aroclor 1221	PP	0.5		CP														
Aroclor 1232	PP	0.5		CP														
Aroclor 1242	PP	0.5		CP														
Aroclor 1248	PP	0.5		CP														
Aroclor 1254	PP	1		CP														
Aroclor 1260	PP	1		CP														
Atrazine	PP			e														
Americium (pCi/l)	R																	
Americium 241 (pCi/l)	R	0.01																
Cesium 134 (pCi/l)	R	1			80 (10)													
Cesium 137 (pCi/l)	R	1																
Gross Alpha (pCi/l)	R	2																
Gross Beta (pCi/l)	R	4																
Plutonium (pCi/l)	R																	
Plutonium 238+239+240 (pCi/l)	R	0.01			15 (10)													
Radium 226+228 (pCi/l)	R	0.5/1 (9)			5 (10)													
Strontium 89+90 (pCi/l)	R	1																
Strontium 90 (pCi/l)	R				8 (10)													
Thorium 230+232 (pCi/l)	R				60 (10)													

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)													Basin Standards (b)		
Parameter	Type	PQL		Method	Human Health Carcinogens/ Noncarcinogens (2) (8)	Aquatic Life (8)			Tables I, II, III (1)			Organics (7)		Water Supply	
		MDL	RFP			Acute Value	Chronic Value	Acute Value	Chronic Value	Agricult- ural Standard (3)	Domestic Water Supply (4)				
												Water and Fish	TVS		TVS
Tritium (pCi/l)	R				20 000 (10)										
Uranium 233+234 (pCi/l)	R														
Uranium 235 (pCi/l)	R	0.6													
Uranium 238 (pCi/l)	R	0.6													
Uranium (Total) (pCi/l)	R														
1,2,4,5-Tetrachlorobenzene	SV			b	2 (8)										
1,2,4-Trichlorobenzene	SV	10		CS			620								
1,2-Dichlorobenzene (Ortho)	SV	10		b	0.05		0.04								
1,2-Diphenylhydrazine	SV	10		CS	620		400								
1,3-Dichlorobenzene (Meta)	SV	10		CS	75		75								
1,4-Dichlorobenzene (Para)	SV	10		CS											
2,4,5-Trichlorophenol	SV	50		CS											
2,4,6-Trichlorophenol	SV	10		CS	2		2								
2,4-Dichlorophenol	SV	10		CS	21		21								
2,4-Dimethylphenol	SV	10		CS											
2,4-Dinitrophenol	SV	50		CS	14		14								
2,4-Dinitrotoluene	SV	10		CS											
2,6-Dinitrophenol	SV	10		CS											
2-Chloronaphthalene	SV	10		CS											
2-Chlorophenol	SV	10		CS											
2-Methylphenol	SV	10		CS											
2-Nitrophenol	SV	10		CS											
2-Nitroaniline	SV	50		CS											
3,3-Dichlorobenzidine	SV	10		CS											
3-Nitroaniline	SV	20		CS											
4,6-Dinitro-2-methylphenol	SV	50		CS											
4-Bromophenyl Phenylether	SV	10		CS											
4-Chloroaniline	SV	10		CS											

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARS/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)											Basin Standards (b)				
Parameter	Type (5)	PQL MDL RFP	CDH (6)	Method (6)	Human Health Carcinogenic/Noncarcinogenic (2) (8)				Tables I II III (1)				Organics (7)		
					Water Supply	Fish	Aquatic Life (8)		Aquatic Life		Agricultural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply	
							Chronic Value	Acute Value	Chronic Value	Acute Value					
4-Chlorophenyl Phenyl Ether	SV	10		CS											
4-Chloro-3-methylphenol	SV	10	50	CS				30							
4-Methylphenol	SV	10		CS											
4-Nitroaniline	SV	50		CS											
4-Nitrophenol	SV	50		CS											
Acenaphthene	SV	10	10	CS				1 700	520						
Anthracene	SV	10	1	CS											
Benazidine	SV	10	10	d	0 0002	0 00012(8)		2 500					0 1	0 01	
Benzoic Acid	SV	50		CS											
Benzo(a)anthracene	SV	10	10	CS											
Benzo(a)pyrene	SV	10	10	CS											
Benzo(b)fluoranthene	SV	10	10	CS											
Benzo(g,h,i)perylene	SV	10	10	CS											
Benzo(k)fluoranthene	SV	10	10	CS											
Benzyl Alcohol	SV	10		CS											
bis(2-Chloroethoxy)methane	SV	10		CS											
bis(2-Chloroethyl)ether	SV	10	10	CS	0 03 (8)	0 03 (8)									
bis(2-Chloropropyl)ether	SV	10	10	CS		1 400									
bis(2-Ethylhexyl)phthalate	SV	10	10	CS		1 8 (8)									
Betadine	SV														
Betyl Benzylphthalate	SV	10	10	CS		3 000									
Chlorinated Ethers	SV														
Chlorinated Naphthalenes	SV														
Chloroalkyl ethers	SV	10		CS											
Chlorophenol	SV	10	50	CS											
Chrysene	SV	10	10	CS		0 0028							1 0	1 0	
Dibenzofuran	SV	10	10	CS											
Dibenz(a,h)anthracene	SV	10	10	CS		0 0028									
Dichlorobenzene	SV	1	1	CS											
Dichlorobenzidine	SV	20	10	CS		0 039									

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARS/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)															Basin Standards (b)	
Parameter	Type (5)	PQL MDL RFP	Method (6)	Human Health Carcinogens/Noncarcinogens (2) (8)			Aquatic Life (8)		Tables I II III (1)				Organics (7)			
				Water Supply	Fish	Water and Fish	Acute Value	Chronic Value	Aquatic Life		Agricultural Standard (3)	Domestic Water Supply (4)	Organics (7)			
									Acute Value (2)	Chronic Value (2)						
Diethylphthalate	SV	10	CS			23 000										
Dimethylphthalate	SV	10	CS			313 000										
Di-n-butylphthalate	SV	10	CS			2 700										
Di-n-octylphthalate	SV	10	CS													
Ethylene Glycol	SV		d													
Fluoranthene	SV	10	CS			42	3 980									
Fluorene	SV	10	CS			0 0028										
Formaldehyde	SV															
Haloethers	SV															
Hexachlorobenzene	SV	10	CS		6	0 00072										
Hexachlorobutadiene	SV	10	CS		1	0 45	90	9 3								
Hexachlorocyclopentadiene	SV	10	CS			240	7	5								
Hexachloroethane	SV	10	CS			1 9	980	540								
Hydrazine	SV															
Indeno(1 2 3-cd)pyrene	SV	10	CS			0 0028										
Isophorone	SV	10	CS		1 050	8 4	117 000	620								
Naphthalene	SV	10	CS			0 0028	2 300									
Nitrobenzene	SV	10	CS		3 5	3 5	27 000									
Nitrophenols	SV															
Nitrosamines	SV															
Nitrosodibutylamine	SV		b			0 0064										
Nitrosodiethylamine	SV		b			0 0008										
Nitrosodimethylamine	SV		b			0 00069										
Nitrosopyrrolidine	SV		b			0 016										
N-Nitrosodiphenylamine	SV	10	CSb			4 9										
N-Nitroso-di-n-dipropylamine	SV	10	CSb			0 005										
Pentachlorinated Ethanes	SV		b													
Pentachlorobenzene	SV		b		6 (8)											
Pentachlorophenol	SV	50	CS		200		9	5 7								
Phenanthrene	SV	10	CS			0 0028										

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)											Basin Standards (b)			
Parameter	Type (5)	PQL MDL RFP	CDH	Method (6)	Human Health			Tables I III (1)				Basin Standards (b)		
					Carcinogens/ Noncarcinogens (2) (8)	Acute Life (8)		Aquatic Life		Domestic Water Supply (4)	Organics (7)			
						Water Supply	Fish	Water and	Acute Value			Chronic Value	Acute Value (2)	Chronic Value (2)
Phenol	SV	10	50	CS		21 000	10 200	2 560			500	1 0		
Phthalate Esters	SV			e										
Polynuclear Aromatic Hydrocarbon	SV		10	b		0 0028								
Vinyl Chloride	SV	10	2	CV	2	2								
1,1,1-Trichloroethane	V	5	1	CV	200	200								
1,1,2-Trichloroethane	V	5	1	CV		0 17		2 400						
1,1,2-Trichloroethane	V	5	1	CV	3	0 6	9 400							
1,1-Dichloroethane	V	5	1	CV										
1,1-Dichloroethane	V	5	1	CV	7	0 057								
1,2-Dichloroethane	V	5	1	CV	0 4	0 4	118 000	20 000						
1,2-Dichloroethane (cis)	V	5	1	a	70									
1,2-Dichloroethane (total)	V	5	1	CV										
1,2-Dichloroethane (trans)	V	5	1	a	100									
1,2-Dichloropropane	V	5	1	CV	0 56 (8)	0 56	23 000	5 700						
1,3-Dichloropropane (cis)	V	5	1	CV		10	6 060	244						
1,3-Dichloropropane (trans)	V	5	1	CV		10	6 060	244						
2-Butanone	V	10		CV										
2-Hexanone	V	10		CV										
4-Methyl-2-pentanone	V	10		CV										
Acetone	V	10		CV										
Acrylonitrile	V		5	c		0 58	7 550	2 600						
Benzene	V	5	1	CV	1	1	5 300							
Bromodichloromethane	V	5	1	CV	0 3	0 3								
Bromoform	V	5	1	CV	4	4								
Bromomethane	V	10	1	CV		48								
Carbon Disulfide	V	5		CV										
Carbon Tetrachloride	V	5	1	CV	0 3	0 25	35 200							
Chlorinated Benzenes	V	10		CV/CS										
Chlorobenzene	V	5	1	CV/CS	100	100								

TABLE A-3 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STATEWIDE AND BASIN (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Statewide Standards (a)															Basin Standards (b)	
Parameter	Type (5)	PQL		Method (6)	Human Health			Aquatic Life (8)		Tables I, II, III (1)				Domestic Water Supply (4)	Organics (7)	
		RFP	MDL		Cardiogenou/ Noncarcinogen (2) (8)	Water Supply	Water and Fish	Acute Value	Chronic Value	Aquatic Life		Agricul- tural Standard (3)	Aquatic Life		Water Supply	
										Acute Value (2)	Chronic Value (2)					
Chloroethane	V	10		CV			6									
Chloroform	V	5		1	CV		6		28,900	1 240						
Chloromethane	V	10		1	CV											
Dibromochloromethane	V	5		1	CV		14	5 7 6								
Dichloroethenes	V			1												
Ethyl Benzene	V	5		1	CV		680	3 100	32 000							
Ethylene Dibromide	V				d											
Ethylene Oxide	V															
Halomethanes	V						100									
Methylene Chloride	V	5		1	CV			4 7 0 0028								
Pyrene	V	10		10	CS											
Styrene	V	5		1	CV											
Tetrachloroethanes	V	5		1	CV											
Tetrachloroethene	V	5		1	CV			0 8	5 280	840						
Toluene	V	5		1	CV		1 000	1 000	17 500							
Trichloroethanes	V	5		1	CV											
Trichloroethene	V	5		1	CV		5	2 7	45 000	21 900						
Vinyl Acetate	V	10			CV											
Xylenes (Total)	V	5			CV											

EXPLANATION OF TABLE

CLP = Contract Laboratory Program
 CDH = Colorado Department of Health
 dis = dissolved
 EPA = Environmental Protection Agency
 MDL = Minimum Detection Limit for radionuclides (pCi/l)
 pCi/l = picocuries per liter
 PCB = polychlorinated biphenyl
 PQL = Practical Quantitation Level
 SS = species specific
 TAL = Target Analyte List
 THM = Total Trihalomethanes
 TIC = Tentatively Identified Compound
 TVS = Table Value Standard (hardness dependent), see Table III in (a)
 ug/l = micrograms per liter
 VOA = Volatile Organic Analysis
 WQCC = Water Quality Control Commission

(1) Table I = physical and biological parameters

Table II = inorganic parameters

Table III = metal parameters

Values in Tables I, II, and III for recreational uses: cold water biota and domestic water supply are not included
 (2) In the absence of specific, numeric standards for non-naturally occurring organics, the narrative standard is interpreted as zero with enforcement based on practical quantification levels (PQLs) as defined by CDH/WQCC or EPA

(3) All are 30-day standards except for nitrate-nitrite

(4) Ammonia, nitrite, chloride, sulfate, copper, iron, manganese, and zinc are 30-day standards; all others are 1-day standards

(5) type abbreviations are: A=anion, B=bacteria, C=cation, I=indicator, FP=field parameter, M=metal, P=pesticide, PP=pesticide/PCB, R=radionuclide, SV=semi-volatile, V=volatile

(6) method abbreviations are: CT=CLP-TAL, NC=non-CLP, CV=CLP-VOA, CS=CLP-SEMI, EP=EPA-PEST, CP=CLP-PEST, E=EPA, a = detected as total in CV

b = detected as TICs in CS, c = detected as TIC in CV, d = not routinely monitored, e = monitored in discharge ponds, f = mixture-individual isomers detected

(7) See Section 3.8.5 (2)(e) in (b)

(8) Where standard is below (more stringent than) PQL (CDH), PQL is standard

(9) MDL for Radium 226 is 0.5 MDL for Radium 228 is 1.0

(10) See section 3.1.1 (f) (2) in (a)

(a) CDH/WQCC Colorado Water Quality Standards 3.1.0 (5 CCR 1002-8) 1/15/1974 amended 10/17/1991 (ARAR)

(Environmental Reporter 726 1001-1020 6/1990)

(b) CDH/WQCC Classifications and Numeric Standards for S. Platte River Basin, Larame River Basin, Republican River Basin

Smoky Hill River Basin 3.8.0 (5 CCR 1002-8) 4/6/1981 amended 2/15/1990 - Basin-wide standards are ARAR

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)											
Parameter	Type (5)	PQL- MDL		Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio- nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
		RFP	CDH					Acute Value	Chronic Value	Woman Creek	Walnut Creek
Bicarbonate	A	10 000		E310 1							
Carbonate	A	10 000		E310 1							
Chloride	A	5 000		E325				250,000	250 000		
Chlorine	A	1,000		E4500				3	3		
Fluoride	A	5 000		E340				10,000	10 000		
N as Nitrate	A	5 000		E353 1							
N as Nitrate+Nitrite	A	5 000		E353 1				1 000	1 000		
N as Nitrite	A	5 000		E354 1				250 000	250 000		
Sulfate	A	5 000		E375 4							
Sulfide	A										
Coliform (Fecal)	B	1		SM9221C							
Ammonia as N	C	5 000		E350				620	60		
Dioxin	D			d		0 00000022			0 000000013		
Sulfur	E	100 000		E600							
Dissolved Oxygen	FP	500		SM4500				2 0	2 0		
pH	FP	0 1		E150 1				5 000	5 000		
Specific Conductance	FP	1		E120 1				6 5-9	6 5-9		
Temperature	FP										
Boron	I	5 000		E6010				750	750		
Total Dissolved Solids	I	10 000		E160 1							
Aluminum	M	200		CT							
Antimony	M	60		CT							
Arsenic	M	10		CT				50			
Arsenic III	M										
Arsenic V	M										
Barium	M	200		CT							
Beryllium	M	5		CT							

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)											
Parameter	Type (5)	PQL MDL		Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio- nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
		RFP	CDH					Acute Value	Chronic Value	Woman Creek	Walnut Creek
Cadmium	M	5		CT				TVS	TVS		
Calcium	M	5 000		CT							
Cesium	M	1 000		NC							
Chromium	M	10		CT				50			
Chromium III	M	5		SW8467196				TVS	TVS		
Chromium VI	M	10		E218 5				TVS	5		
Cobalt	M	50		CT				TVS	300 (3)		
Copper	M	25		CT				TVS	TVS		
Cyanide	M	10		CT				5	5		
Iron	M	100		CT				TVS	TVS		
Lead	M	5		CT							
Lithium	M	100		NC							
Magnesium	M	5000		CT					50 (3)		
Manganese	M	15		CT					0 01		
Mercury	M	0 2		CT					TVS		
Molybdenum	M	200		NC							
Nickel	M	40		CT				TVS	TVS		
Potassium	M	5000		CT							
Selenium	M	5		CT							
Silver	M	10		CT				10	TVS		
Sodium	M	5000		CT				TVS	TVS		
Strontium	M	200		NC							
Thallium	M	10		CT							
Tin	M	200		NC							
Titanium	M	10		E6010							
Tungsten	M	10		E6010							
Vanadium	M	50		CT				TVS	TVS		
Zinc	M	20		CT							
2,4,5-TP Silver	P			d	10						

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARS/IBC3 (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)										
Parameter	Type (5)	PQL		Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio- nuclide	Stream Segment Table (5)		Table 2 Radionuclides Waters Creek
		MDL	RFP					Acute Value	Chronic Value	
Permethrin	P			d	100					
2,4-D	P			d						
Acrolein	P			10						
Aldicarb	P			10						
Aldrin	P		0.05	0.1	0.002 (6)	0.000074			0.000074	
Bromacil	P				36					
Carbofuran	P			d						
Chloranil	P			E619						
Chlordane (Alpha)	P	0.5		1	0.03 (6)	0.00046			0.00046	
Chlordane (Gamma)	P	0.5		1	0.03 (6)	0.00046			0.00046	
Chlorpyrifos	P			0.1						
DDT	P	0.1		0.1	0.1 (6)	0.000024			0.000024	
DDT Metabolite (DDD)	P	0.1		0.1						
DDT Metabolite (DDE)	P	0.1		0.1						
Demeton	P	0.1		0.1						
Diazinon	P			1						
Disulfoton	P	0.1		0.1	0.002 (6)	0.000071			0.000071	
Endosulfan I	P	0.05		0.1						
Endosulfan II	P	0.1		0.1						
Endosulfan Sulfate	P	0.1		0.1						
Endrin	P	0.1		0.1	0.2					
Endrin Aldehyde	P			0.1						
Endrin Ketone	P			0.1						
Guthion	P	0.1								
Heptachlor	P			1.5						
Heptachlor Epoxide	P	0.05		0.05	0.008 (6)	0.00028			0.00028	
Hexachlorocyclohexane, Alpha	P	0.05		0.05	0.004 (6)					
Hexachlorocyclohexane, Beta	P	0.05		0.05		0.0092			0.0092	
Hexachlorocyclohexane, BHC	P	0.05		0.05		0.0163			0.0163	
Hexachlorocyclohexane, Delta	P	0.05		0.05						
Hexachlorocyclohexane, Tech	P	0.05		0.2		0.0123			0.0123	

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)										
Parameter	Type (5)	PQL		Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio- nuclide	Stream Segment Table (5)		Table 2 Radionuclides Woman Creek Creek
		MDL	CDH					Acute Value	Chronic Value	
Permethrin	P	0.05	0.05	CP	4	0.0186			0.0186	
Hexachlorocyclohexane	P		0.2							
Lindane	P		0.5	CP	100					
Malathion	P	0.5	0.1							
Methoxychlor	P									
Mirex	P									
Parathion	P									
PCBs	P	0.5	1	CP	0.005 (6)	0.000079			0.000079	
Simazine	P	1	5	e	5	4			4	
Toxaphene	P									
Vapona 2	P									
Aroclor 1016	PP	0.5		CP						
Aroclor 1221	PP	0.5		CP						
Aroclor 1232	PP	0.5		CP						
Aroclor 1242	PP	0.5		CP						
Aroclor 1248	PP	0.5		CP						
Aroclor 1254	PP	1		CP						
Aroclor 1260	PP	1		CP						
Atrazine	PP			e		3			3	
Americium (pCi/l)	R									0.05
Americium 241 (pCi/l)	R	0.01					30			0.05
Cesium 134 (pCi/l)	R	1			80		80			80
Cesium 137 (pCi/l)	R	1								7
Gross Alpha (pCi/l)	R	2								11
Gross Beta (pCi/l)	R	4								19
Plutonium (pCi/l)	R									0.05
Plutonium 238+239+240 (pCi/l)	R	0.01					15			0.05
Radium 226+228 (pCi/l)	R	0.5/1	0 (7)				5			8
Strontium 89+90 (pCi/l)	R	1					8			8
Strontium 90 (pCi/l)	R						60			
Thorium 230+232 (pCi/l)	R									

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARS/TBCs (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)											
Parameter	Type (5)	PQL		Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio- nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
		MDL	RFP					Acute Value	Chronic Value	Wagon Creek	Walnut Creek
Tritium (pCi/l)	R						20 000			500	500
Uranium 233+234 (pCi/l)	R										
Uranium 235 (pCi/l)	R	0.6									
Uranium 238 (pCi/l)	R	0.6									
Uranium (Total) (pCi/l)	R						40			5	10
1,2,4,5-Tetrachlorobenzene	SV		10	b	2 (6)						
1,2,4-Trichlorobenzene	SV	10		CS							
1,2-Dichlorobenzene (Ortho)	SV	10	1	CS	620						
1,2-Diphenylhydrazine	SV			b	0.05 (6)						
1,3-Dichlorobenzene (Meta)	SV	10	1	CS	620						
1,4-Dichlorobenzene (Para)	SV	10	1	CS	75						
2,4,5-Trichlorophenol	SV	50		CS	700						
2,4,6-Trichlorophenol	SV	10	50	CS	2.0 (6)	1.2			1.2		
2,4-Dichlorophenol	SV	10	50	CS	21 (6)						
2,4-Dimethylphenol	SV	10	50	CS							
2,4-Dinitrophenol	SV	50	50	CS							
2,4-Dinitrotoluene	SV	10	10	CS							
2,6-Dinitrotoluene	SV	10	10	CS							
2-Chloronaphthalene	SV	10	10	CS							
2-Chlorophenol	SV	10	50	CS							
2-Methylnaphthalene	SV	10		CS							
2-Methylphenol	SV	10		CS							
2-Nitroaniline	SV	50		CS							
2-Nitrophenol	SV	10		CS							
3,3-Dichlorobenzidine	SV	20	10	CS		0.01				0.01	
3-Nitroaniline	SV	50		CS							
4,6-Dinitro-2-methylphenol	SV	50	50	CS							
4-Bromophenyl Phenylether	SV	10		CS							
4-Chloroaniline	SV	10		CS							

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)											
Parameter	Type (5)	PQL MDL		Method (6)	Tables A, B (1)	Table C Fish & Water Ingestion	Table D Radio- nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
		RFP	CDH					Acute Value	Chronic Value	Woman Creek	Walnut Creek
4-Chlorophenyl Phenyl Ether	SV	10		CS							
4-Chloro-3-methylphenol	SV	10	50	CS							
4-Methylphenol	SV	10		CS							
4-Nitroaniline	SV	50		CS							
4-Nitrophenol	SV	50		CS							
Acenaphthene	SV	10	10	CS							
Anthracene	SV	10	1	CS							
Benidine	SV		10	d	0.0002 (6)	0.00012			0.00012		
Benzoic Acid	SV	50		CS							
Benzo(a)anthracene	SV	10	10	CS							
Benzo(a)pyrene	SV	10	10	CS							
Benzo(b)fluoranthene	SV	10	10	CS							
Benzo(g,h,i)perylene	SV	10	10	CS							
Benzo(k)fluoranthene	SV	10	10	CS							
Benzyl Alcohol	SV	10		CS							
bis(2-Chloroethoxy)methane	SV	10		CS							
bis(2-Chloroethoxy)ether	SV	10	10	CS	0.03 (6)	0.0000037			0.0000037		
bis(2-Chloroisopropoxy)ether	SV	10	10	CS							
bis(2-Ethylhexyl)phthalate	SV	10	10	CS							
Butadiene	SV										
Butyl Benzylphthalate	SV	10		CS							
Chlorinated Ethers	SV										
Chlorinated Naphthalenes	SV										
Chloroalkyl ethers	SV	10		CS							
Chlorophenol	SV	10	50								
Chrysene	SV	10	10	CS							
Dibenzofuran	SV	10		CS							
Dibenz(a,h)anthracene	SV	10	10	CS							
Dichlorobenzenes	SV		1								
Dichlorobenzidine	SV	20	10	CS		0.01			0.01		

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)											
Parameter	Type (5)	PQL		Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio- nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
		MDL	RFP					Acute Value	Chronic Value	Woman Creek	Walnut Creek
			CDH								
Diethylphthalate	SV	10	10	CS							
Dimethylphthalate	SV	10	10	CS							
Di-n-butylphthalate	SV	10	10	CS							
Di-n-octylphthalate	SV	10		CS							
Ethylene Glycol	SV			d							
Fluoranthene	SV	10	10	CS							
Fluorene	SV	10	10	CS							
Formaldehyde	SV										
Haloothers	SV										
Hexachlorobenzene	SV	10	10	CS	0.02 (6)	0.00072			0.00072		
Hexachlorobutadiene	SV	10	10	CS	14	0.45			0.45		
Hexachlorocyclopentadiene	SV	10	10	CS	49				1.9		
Hexachloroethane	SV	10	10	CS							
Hydrazine	SV										
Indeno(1,2,3-cd)pyrene	SV	10	10	CS							
Isophorone	SV	10	10	CS	1.050						
Naphthalene	SV	10	10	CS							
Nitrobenzene	SV	10	10	CS	3.5 (6)						
Nitrophenols	SV										
Nitrosamines	SV										
Nitrosodibutylamine	SV		10	b		0.0064			0.0064		
Nitrosodimethylamine	SV		10	b		0.0008			0.0008		
Nitrosodimethylamine	SV		10	b		0.0014			0.0014		
Nitrosopyrrolidine	SV		10	b		0.016			0.016		
N-Nitrosodiphenylamine	SV	10	10	CSb		4.9			4.9		
N-Nitroso-di-n-dipropylamine	SV	10	10	CSb							
Pentachlorinated Ethanes	SV			b							
Pentachlorobenzene	SV		10	b	6 (6)						
Pentachlorophenol	SV	50	50	CS	200						
Phenanthrene	SV	10	10	CS							

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)											
Parameter	Type (5)	PQL		Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio- nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
		MDL	RFP					Acute Value	Chronic Value	Woman Creek	Walnut Creek
Phenol	SV		10	50							
Phthalate Esters	SV			e							
Polynuclear Aromatic Hydrocarbons	SV			b							
Vinyl Chloride	SV		10	2	2	0.0028			0.0028		
1,1 1-Trichloroethane	V		5	1	200						
1,1 2-Tetrachloroethane	V		5	1		0.17			0.17		
1,1 2-Trichloroethane	V		5	1	28	0.60			0.60		
1 1 1-Dichloroethane	V		5		7						
1,1-Dichloroethene	V		5	1	5						
1,2-Dichloroethane	V		5	1	70						
1,2-Dichloroethene (cis)	V		5	1							
1,2-Dichloroethene (total)	V		5								
1,2-Dichloroethene (trans)	V		5	1	70						
1 2-Dichloropropene	V		5	1		0.56 (6)					
1,2-Dichloropropene (cis)	V		5	1							
1,3-Dichloropropene (trans)	V		5	1							
2-Butanone	V		10								
2-Hexanone	V		10								
4-Methyl-2-pentanone	V		10								
Acetone	V		10								
Acrylonitrile	V			5		0.058			0.058		
Benzene	V		5	1	5						
Bromodichloromethane	V		5	1							
Bromoform	V		5	1							
Bromomethane	V		5	1							
Carbon Disulfide	V		10	1							
Carbon Tetrachloride	V		5		5						
Chlorinated Benzenes	V		1								
Chlorobenzene	V		10		300						
	V		5	1							

TABLE A-4 POTENTIAL CHEMICAL-SPECIFIC ARARs/TBCs (February 1, 1992)
STREAM SEGMENT (CDH/WQCC) SURFACE WATER QUALITY STANDARDS (ug/l)

Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)										
Parameter	Type (5)	PQL		Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio- acclide	Stream Segment Table (5)		Table 2 Radionuclides Wetland Creek Creek
		MDL	RFP					Acute Value	Chronic Value	
Parameter				CDH						
Chloroethane	V		10							
Chloroform	V		5	1		0.19			0.19	
Chloromethane	V		10	1						
Dibromochloromethane	V		5	1						
Dichloroethanes	V		5	1						
Ethyl Benzene	V		5	1	680					
Ethylene Dibromide	V		5	1						
Ethylene Oxide	V									
Halomethanes	V				100	0.19			0.19	
Methylene Chloride	V		5	1						
Pyrene	V		10	10						
Styrene	V		5	1						
Tetrachloroethanes	V		5	1		0.8			0.8	
Tetrachloroethene	V		5	1	10					
Toluene	V		5	1	2,420					
Trichloroethanes	V		5	1						
Trichloroethene	V		5	1	5					
Vinyl Acetate	V		10	1						
Xylenes (Total)	V		5							

EXPLANATION OF TABLE

* = Total trihalomethanes chloroform bromoform bromodichloromethane dibromochloromethane

CLP = Contract Laboratory Program
 CDH = Colorado Department of Health
 dis = dissolved
 EPA = Environmental Protection Agency
 MDL = Minimum Detection Limit for radionuclides (pCi/l)
 pCi/l = picocuries per liter
 PCB = polychlorinated biphenyl
 PQL = Practical Quantitation Level
 RFP = Rocky Flats Plant
 SS = species specific
 TAL = Target Analyte List
 THM = Total Trihalomethanes
 TIC = Tentatively Identified Compound
 TVS = Table Value Standard (hardness dependent) see Table III in (a)
 ug/l = micrograms per liter
 VOA = Volatile Organic Analysis
 WQCC = Water Quality Control Commission

(1) In the absence of specific, numeric standards for non-naturally occurring organics the narrative standard is interpreted as zero with enforcement based on practical quantification levels (PQLs) as defined by CDH/WQCC or EPA

(2) Ammonia sulfide, chloride sulfate, copper, iron manganese, and zinc are 30-day standards all others are 1-day standards

(3) Lowest value given dissolved or total recoverable

(4) Segment 5 standards are goals

(5) Includes Table 1 Additional Organic Chemical Standards (chronic only)

(6) Standard is below (more stringent than) PQL, therefore PQL is standard

(7) MDL for Radium 226 is 0.5 MDL for Radium 228 is 1.0

(a) CDH/WQCC, Colorado Water Quality Standards 310 (5 CCR 1002-8) 1/15/1974 amended 9/30/1989 (ARAR)
 (Environmental Reporter 726 1001-1020 6/1990)

(b) CDH/WQCC Classifications and Numeric Standards for S. Platte River Basin Laramie River Basin Republican River Basin
 Smoky Hill River Basin 380 (5 CCR 1002-8) 4/6/1981 amended 2/15/1990 - Basin-wide standards are ARAR site-specific standards are TBC

APPENDIX B
TECHNOLOGY DATA SUMMARIES FOR GROUNDWATER/SURFACE WATER
TECHNOLOGIES REVIEWED IN THE ANNUAL REPORT

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ACTIVATED CARBON

Description

Granular Activated Carbon (GAC) adsorption is based on the attraction of organic molecules in solution to the surface of the activated carbon. The adsorption process is dependent on the strength of the molecular attraction between the carbon and the organic contaminant, the type and characteristics of the carbon, and the pH and temperature of the solution. Nonpolar organic compounds of low water solubility are most easily adsorbed (U S EPA 1986a).

GAC adsorption is one of the most frequently used techniques for treating aqueous streams contaminated with organics. The carbon is placed in columns that are operated until the effluent concentration reaches unacceptable levels. At this point the carbon has become saturated with the contaminants and must be regenerated for reuse. The carbon is generally regenerated thermally. Pretreatment is typically required for removal of oil, grease, and suspended solids.

Applications

GAC adsorption is an effective process for removing a variety of organics from water. It has been successful for carbon tetrachloride, chloroform, DDT, benzene, acetone, methylene chloride, phenol, trichloroethylene, and xylene among others (U S EPA 1985). In general, GAC can reduce these contaminants from mg/L concentrations to low ug/L concentrations.

The Rocky Mountain Arsenal has used GAC adsorption extensively for treatment of groundwater (PMSO 1987a, 1987b). Contaminants removed include trichloroethylene, dibromochloropropane, diisopropylmethyl phosphonate, dicyclopentadiene, and various pesticides such as dieldrin and aldrin.

Advantages and Disadvantages

GAC adsorption is a well known and developed technique for removing organic contaminants from water. The adsorbability varies between different classes of organics, but most of them can be removed by this method. The major disadvantage of GAC adsorption is that it requires energy-intensive regeneration or disposal of the carbon, and large amounts of carbon are required for poorly adsorbable compounds, such as chlorinated volatile organics. Residuals include spent carbon and/or waste streams from the regeneration process.

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No 6

ACTIVATED SLUDGE

Description

The activated sludge process uses microorganisms to remove organic contaminants from water. The microorganisms use the organics as a substrate for growth and as an energy source. Adequate nutrients, nitrogen, and phosphorus are required for microbial activity. As the microorganisms proliferate, they form a biomass which is referred to as the "activated sludge." This material is kept in close contact with the wastewater by air agitation, which also provides the oxygen needed to sustain the process. The biomass has the ability to adsorb particulate and dissolved metals and radionuclides.

The biologically treated wastewater is sent to a clarifier where the biomass is removed by settling. Some of this settled sludge is returned to the process. The remainder of the sludge must be dewatered and digested or disposed.

Applications

Most organic compounds can be biologically degraded by the appropriate microorganisms. Some compounds, such as large, complex chlorinated organics and some volatile chlorinated organics, are more easily degraded anaerobically than aerobically. High concentrations of organics or the presence of metals may be toxic to the organisms, and pretreatment may be required.

Advantages and Disadvantages

The major advantage of biodegradation is that it is a natural process that will generally reduce the toxicity of the contaminant. Disadvantages of biological reactors include generation of large amounts of sludge (especially in aerobic processes), possible formation of toxic by-products, and relatively low removal efficiencies that make additional treatment necessary. Emissions of volatile organics may also be a problem. It is also generally difficult to treat very low levels of organics. High or varying concentrations of organics or metals may have a toxic effect on the microorganisms.

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ADSORPTION

Description

Adsorption is a term commonly used to refer to both adsorption and absorption. Adsorption is the physical adhesion of molecules or particles to the surface of a solid adsorbent without chemical reaction. Absorption involves the transfer of the molecules or particles from one phase to the other so that they actually become a part of the other phase (medium). Absorption may be physical or chemical in nature.

A number of different adsorption processes exist for treatment of metals and radionuclide contaminants in water. These include activated alumina, a ferrite process, and other processes (U.S. EPA 1985, 1986a, Schweitzer 1979).

Activated Alumina Activated alumina is a porous form of aluminum oxide with a large surface area. It will adsorb liquids, vapors, and gases. For removal of aqueous contaminants, activated alumina is typically used in a column similar to that for ion exchange. It has proven to be successful in the removal of arsenic and fluoride from groundwater (Rubel 1980, Frankel and Juergens 1980). Adsorbed species can be removed by flushing the column with a suitable chemical solution, generating a concentrated side stream.

Ferrite Process This process involves the introduction of ferrite particles into a waste stream. Inorganic contaminants present in the waste stream will sorb to the particles which are then removed by physical separation. The ferrite process also has the capability of being used in a column similar to ion exchange.

Applications

Activated alumina is used to remove small amounts of fluoride and arsenic from potable water and wastewater (Rubel 1980, Frankel and Juergens 1980). The fluoride adsorption process is pH dependent with optimal removal occurring at pH 5. Research indicates that selenium can also be removed using activated alumina (Yuan et al. 1983).

Advantages and Disadvantages

Adsorption of metals and radionuclides is a standard technique for removal and concentration of these contaminants. The major disadvantage to adsorption processes is that they produce a concentrated liquid side stream resulting from regeneration. If not regenerated, the sorbent must be disposed as a solid waste.

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AEROBIC BIOLOGICAL REACTOR

Description

The aerobic biological reactor is a biodegradation system used for destruction of organic compounds in aqueous media. The process uses a bioreactor packed with plastic media which acts as a support for a film of bacterial growth. The packing is completely submerged in the bioreactor. Air or oxygen is pumped into the bioreactor to maintain aerobic conditions. In addition to oxygen, it may be necessary to add nutrients to the bioreactor for some applications. The submerged aerobic fixed film reactor requires less space than an aeration basin. This is due to the greater surface area provided by the bacterial film, and to the higher oxygen loading provided to the microorganisms.

Applications

The process is applicable to aqueous media contaminated with organic constituents which are amenable to biodegradation. The submerged aerobic fixed film reactor has been shown to be effective for relatively low concentrations in the influent stream. This is an advantage over other bioreactors, such as rotating biological contractors or aeration basins, which are not effective for low concentrations of organic contaminants. It may be necessary to combine the process with treatment of the bioreactor effluent by granular activated carbon for adsorption of non-biodegradable organic constituents.

Submerged aerobic fixed film technology is not applicable to radionuclides or heavy metals. Some metals have a toxic effect on the bacterial growth and must be avoided. Certain halogenated organic compounds are not readily destroyed by strictly aerobic biodegradation and are not amenable to treatment by this technology.

Advantages and Disadvantages

The primary advantages of the aerobic biological reactor are applicability to a broad range of organic constituents, effectiveness for treatment of relatively low contaminant concentrations, and relatively low capital and operating costs.

The technology is not effective for all organic contaminants, it may be necessary to combine the process with a treatment technology for the bioreactor effluent.

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Bioreactors Remediation, V 2, No 7

ALTERNATING CURRENT ELECTROCOAGULATION

Description

In this technology, an alternating (A-C) current electrocoagulator imposes an electric field on stable suspensions and emulsions and rearranges surface charges, which in turn facilitates particle flocculation and separation. Production separation is accomplished in conventional gravity separation and/or decant vessels. After the product separation step, each phase (oil, water, solid) is removed for reuse, recycling, further treatment or disposal. The technology can be employed in conjunction with conventional water treatment systems, including those relying on metal precipitation, membrane separation technologies, mobile dewatering and incineration units, and soil extraction systems.

Applications

The A-C electrocoagulation technology can be applied to a variety of aqueous-based suspensions and emulsions typically generated from contaminated groundwater surface runoff, landfill leachate, truck wash, scrubber solutions, treated effluents, and extract solutions. The suspensions include solids such as inorganic and organic pigments, clays, metallic powders, metal ores, and natural colloidal matter. The emulsions include an array of organic solid and liquid contaminants, including petroleum-based by-products.

Advantages and Disadvantages

Liquid/liquid and solid/liquid phase separations are achieved without the use of expensive polyelectrolytes. Generally, the rate of separation is faster than with methods that employ chemical flocculants, and the solids are often more dense than those resulting from chemical treatment. The process is also free of the excess waste solids attributed to chemical aids.

References

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AEROBIC REDUCTIVE DECHLORINATION

Description

Most of the environmental contamination by chlorinated organics is in the form of complex commercial mixtures containing numerous compounds with varying degrees of chlorination. Biodegradation of this large number of distinct compounds therefore requires broad enzymatic specificity. Additionally, chlorinated organic materials frequently resist microbial degradation. Although these complex chlorinated mixtures are difficult to degrade, the aerobic bacterial degradation of chlorinated organics has been demonstrated in the laboratory.

Applications

This process is applicable to soils, sediments, and aqueous streams contaminated with chlorinated solvents.

Advantages and Disadvantages

This process would completely destroy the chlorinated organic compounds, converting them to cell material, carbon dioxide, and water.

This process is currently in the early development stage, and more research is required to evaluate effectiveness, implementability, and economics.

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ANAEROBIC BIOLOGICAL ACTIVATED CARBON PROCESS

Description

The anaerobic biological activated carbon (AnBAC) technology is being developed to treat wastes containing high concentrations of organics. The process uses a granular activated carbon bed operated under anaerobic conditions. The carbon serves to both adsorb and immobilize organic contaminants and support the microorganisms that feed on the contaminants. The process has been demonstrated at the bench scale and pilot scale for treating wastes containing high concentrations of phenol and formaldehyde.

Applications

This process is applicable to treating aqueous streams containing high concentrations of biodegradable organics.

Advantages and Disadvantages

This technology destroys toxic organics, rendering them harmless to the environment. The process may offer an economic way to treat concentrated waste streams.

The process is not commercially available and requires more study to assess effectiveness, implementability, and economics. Additional treatment would probably be required to meet stringent effluent quality criteria. This technology requires very long startup periods before the biological process begins to effectively degrade the contaminants.

References

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- Obayashi, Alan W. and Joseph M. Gorgan. 1985. *Management of Industrial Pollutants by Anaerobic Processes*. Lewis Publishers, Inc., Chelsea, Michigan.
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ANAEROBIC REDUCTIVE DECHLORINATION

Description

This is a biological treatment process that occurs in the absence of oxygen. The process was first observed to take place naturally in anaerobic environments such as river or lake sediments.

The anaerobic dechlorination of Aroclor 1242 by microorganisms in Hudson River sediments has been demonstrated in the laboratory. Tests showed that the PCB mixture was dechlorinated so extensively that it was converted from 85% tri- and tetra-chlorinated products. The end result of this natural process is the conversion of the more highly chlorinated PCBs into compounds of low toxicity that can be further degraded aerobically.

Applications

The process is applicable to both in situ and conventional treatment of soils and sediments contaminated by PCBs. The process may also be applicable to aqueous streams.

Advantages and Disadvantages

The process destroys the toxic PCB compounds. However, the process is currently in the early stages of development, and minimal information on effectiveness, implementability, and economics is available.

References

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AQUA DETOX (Low Vacuum Steam Stripping)

Description

This process simultaneously treats groundwater and soil contaminated with volatile organic compounds. The integrated system consists of two basic processes: a vacuum stripping tower that uses low pressure steam to treat contaminated groundwater, and a soil gas vapor extraction/reinjection (SVE) process to treat contaminated soil. The two processes form a closed loop system that provides simultaneous in situ remediation of contaminated groundwater and soil with no air emissions.

The SVE system uses a vacuum to treat a VOC-contaminated soil, inducing air flow through the soil to remove vapor phase VOCs with the extracted soil gas. Carbon beds then treat the soil gas to remove additional VOCs before reinjection into the ground. The vacuum stripping tower and SVE system share a granulated activated carbon (GAC) unit.

A key component of the closed-loop system is a vent header unit. This unit collects the noncondensable gases extracted from the groundwater or air that may leak into the portion of the process operating below atmospheric pressure. The system condenses and treats the steam used to regenerate the carbon beds.

By-products of the system include a free-phase product and treated water. Occasional disposal of spent carbon will also be required.

Applications

This technology removes VOCs, including chlorinated hydrocarbons, in groundwater and soil. Sites suitable for this technology include those with both contaminated groundwater and contaminated soil.

Advantages and Disadvantages

This technology may offer economic advantages when both soil and groundwater must be remediated. The process may produce a recyclable product that could offset some of the costs.

Disadvantages relate primarily to system complexity and the need for highly trained operators.

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BIODENITRIFICATION

Description

This is a biological process for removing nitrates from water. The process is accomplished anaerobically, with methanol added as a carbon source. The process can be carried out in plug-flow reactors, complete-mix reactors, and trickling filters.

Applications

This process is used to remove nitrates from aqueous wastes. It is frequently used as the second step of a two-stage process. In the first stage, termed the "nitrification" step, ammonia is converted aerobically into nitrate, which is then removed by biodenitrification.

Advantages and Disadvantages

The process offers an economic method for removing nitrates from water. The process is sensitive to shock loadings and requires trained operators.

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BIOSORPTION (BIOACCUMULATION)

Description

Biosorption (bioaccumulation) consists of both the accumulation of contaminants by bacteria, algae, and or plants, and the adsorption of contaminants to the cell wall. Several plant, bacteria, fungi, and algae species are effective at bioaccumulating/adsorbing metals. Of these, only plants are effective in soil matrices. Algasorb is an algae that has been immobilized in a silica gel polymer that acts much like an ion-exchange resin. The heavy metals will adsorb to the cell wall. In plants, the heavy metals are taken up through the root system.

Applications

This process is primarily applicable to groundwater and surface waters. It has been effective in removing heavy metals, and inorganics, including, but not limited to cadmium, silver, aluminum, chromium, cobalt, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, platinum, uranium, vanadium, zinc, and dissolved solids.

Advantages and Disadvantages

This process may offer economic advantages over more conventional technologies. However, the technology is very new and much more information is required to assess its effectiveness and economics. The removed contaminants are transferred to a biomass that will require further treatment.

References

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CARBON DIOXIDE EXTRACTION

Description

In this process, carbon dioxide is used to remove organic constituents from water, soil, or sludge. The process is based on the fact that some organics are soluble in carbon dioxide when pressurized above its critical point. When the carbon dioxide and the waste are contacted, the contaminants of concern transfer from the waste matrix to the carbon dioxide. The carbon dioxide is then depressurized, and the waste and solvent are then separated. At this point, the waste matrix may be disposed or treated further, as appropriate. The carbon dioxide may be recompressed for reuse.

Applications

This process is applicable to a wide variety of constituents.

Advantages and Disadvantages

The primary advantages of carbon dioxide extraction is its applicability to a wide range of contaminants.

Costs of carbon dioxide extraction are higher than for adsorption or stripping methods. In most cases, extraction will be effective for a limited number of the constituents in the waste matrix, necessitating further treatment of the waste. Recovered contaminants will require treatment prior to disposal.

Additionally, the system is fairly complex and requires highly trained operators.

References

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U.S. EPA. 1988. The Superfund Innovative Technology Evaluation Program. Technology Profiles. EPA/540/5-88/003. November 1988.

CATALYTIC OXIDATION

Description

Catalytic oxidation is used to destroy organic compounds in an aqueous medium. The catalyst lowers the activation energy of the oxidation reaction so that significant rates of destruction can be realized. An oxidizing chemical addition may be required.

Applications

Catalytic oxidation is potentially applicable to a wide range of organic compounds in water. The proper selection of catalyst and reaction temperature is critical.

Advantages and Disadvantages

Catalytic oxidation may produce complete destruction of dissolved organic compounds at low energy use and chemical use. The technology is still in the experimental stage of development.

References

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Van der Vaart, D. T., W. M. Vatvuk, and A. H. Wehe. 1991, January. Thermal Catalytic Incinerators for the Control of VOCs. J. Air Waste Management Association, V. 41, no. 1.

COMETABOLISM BIOLOGICAL PROCESS

Description

This process involves the biological treatment of chlorinated organic compounds via cometabolism of the contaminant using methane or butane as the primary substrate. The hydrocarbon waste streams, which includes water or air, are remediated using a sand or soil bed containing bacteria capable of metabolizing the contaminants to water, carbon dioxide, and trace inorganic salts.

Although chlorinated organic compounds are generally resistant to biodegradation, recent work has shown that bacteria that oxidize gaseous hydrocarbons such as methane or propane are also able to cometabolically oxidize trichloroethylene (TCE) and other low molecular weight halogenated compounds.

Application

This process is applicable to aqueous streams containing low concentrations of chlorinated organics such as TCE and trichloroethane (TCA).

Advantages and Disadvantages

This process results in the destruction of the organic contaminants to form innocuous compounds.

This process has been tested at bench scale only, and more information is required to determine potential effectiveness and costs. The process is very sensitive to influent contaminant concentration and may be difficult to control.

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CONTACT STABILIZATION

Description

Contact stabilization is a form of the activated sludge where aeration is carried out in two phases. Two types of tanks are used: (1) the contact tank where contaminants are adsorbed and absorbed on the microbic masses, and (2) the stabilization tank where the microbial solids, which have been removed in a final settling tank, are partially stabilized by re-aeration before being recycled to the contact tank.

Since most of the aeration is done on the relatively small volume of solids in the stabilization tank, the operating costs are reduced relative to conventional activated sludge processes. Additionally, smaller tank sizes are required, resulting in lower capital costs.

Applications

Applications are the same as for conventional activated sludge technology.

Advantages and Disadvantages

Advantages and disadvantages are similar to activated sludge. However, this process may offer lower capital and operating costs in specific applications.

References

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Parker, Dr. Homer W. 1975. Wastewater Systems Engineering. Prentice-Hall, Inc., Englewood Cliffs, NJ.

EMULSION LIQUID MEMBRANE EXTRACTION

Description

Emulsion liquid membranes (ELMs) consist of emulsion globules that are mixed with a contaminant-containing waste stream. In a typical application, oil, which acts as the membrane medium, is mixed with a chemical extraction agent. The result is an emulsion in which the extraction agent is dispersed within oil globules. The oil acts as a membrane through which contaminants diffuse for subsequent reaction with the internal reagent. By mixing the oil/reagent emulsion with the waste stream, contaminants can be removed from the waste and concentrated in the emulsion globules. This process is sometimes referred to as double emulsion extraction because an emulsion is first made of oil and reagent, followed by emulsification of the oil and reagent globules with the waste stream.

The ELM system is potentially much more efficient than simple solvent/solvent extraction. If the internal phase is selected to react with the solute in the external phase, the driving force for solute removal is increased substantially. The extraction of uranium (VI) from weakly acidic aqueous solutions has been studied using emulsions containing benzylacetone or dibenzylmethane and tributylphosphate.

Applications

This technology is potentially applicable for extracting organics from aqueous waste streams. It can be used for treating wastewaters containing both high and low concentrations of contaminants.

Advantages and Disadvantages

In addition to being less susceptible to problems with suspended solids, ELM treatment also requires much smaller quantities of chemical separating agents than do more conventional techniques. Besides the obvious savings in solvent costs due to reduced volumes, lowest capital expenditures are also possible because extraction vessels and pumping equipment can be smaller and fewer in number. Furthermore, solvent selection is much more flexible than with conventional extraction processes because a membrane-phase preference for the solute is not required. Consequently, solvents can be chosen based on factors like cost, availability, and physical properties, rather than partitioning performance.

This process has not been demonstrated in full-scale treatment applications. Therefore, an assessment of costs, implementability, and effectiveness cannot be made at this time.

References

Two-Step Liquid Membrane Process Tested on Uranium, Other Contaminants in Ground Water 1991,
May 2 HazTECH News V 6, no 9

ENZYMATIC MICROBIAL REDUCTION

Description

In this process, Fe (III)-reducing bacteria, GS-15 and *Shewanella putrefaciens* gain energy for growth by enzymatically coupling the oxidation of organic matter of H_2 to the reduction of U(VI) to U(IV). Since uranium is highly insoluble in its reduced state, microbial reduction can effectively remove dissolved uranium from surface waters and groundwaters.

Applications

Enzymatic microbial reduction is a potential means of removing dissolved uranium from contaminated water and waste streams. Other radionuclides, such as plutonium and technetium might also be removed in a similar manner.

Advantages and Disadvantages

Microbial reduction has been shown to oxidize organic contaminants such as U(VI)-reducing microorganisms which might be able to simultaneously convert the organic contaminants to carbon dioxide while precipitating the radioactive metal.

References

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- Bumpus, John A Biodegradation of Organopollutants by Phanerochaete Chrysosporium Practical Considerations Land Disposal, Remedial Action, Incineration and Treatment of Hazardous Waste EPA/600/9-87/015
- Bumpus, John A , Ming Tien, David Wright, and Stephen D Aust 1985 Oxidation of Persistent Environmental Pollutants by a White Rot Fungus Science, V 228 June 1985
- Bumpus, John A and Stephen D Aust 1987 Biodegradation of Chlorinated Organic Compounds by Phanerochaete Chrysosporium, a Wood-Rotting Fungus ACS Symposium Series 33B American Chemical Society, Washington, D C , 1987
- Fungus Could Help Clean the Environment R&D Magazine, October 1991

Glaser, J A 1988 Wood-Degrading Fungi as Degradars of Hazardous Waste EPA/600/D-88/258
November 1988

Roy, Kimberly A 1989 White Rot Fungus - Acquiring a Taste for Hazardous Waste Hazmat World,
December 1989

EXTENDED AERATION

Description

Extended aeration systems provide long-term aeration in a completely mixed activated sludge process. The system requires that microorganisms exist in the endogenous phase by maintaining a low food-to-microorganism ratio in the system. In the endogenous phase, the microorganisms are basically near starvation and are consuming each other. This results in the production of lower amounts of wasted sludge.

This process basically requires a steel or concrete tank fitted with air diffusers at the bottom. Systems are typically sized to provide approximately 24 hours of detention. The treated effluent then flows through a clarifier for removal of suspended solids. Additional treatment can be included as required to meet effluent criteria.

Applications

This process is used to process wastewaters containing high concentrations of biodegradable organics. Chlorinated hydrocarbons are not effectively biodegraded.

Advantages and Disadvantages

Advantages and disadvantages are the same as for conventional activated sludge. However, extended aeration is better able to handle shock loadings or underloadings without detrimental effects on system performance.

Additional treatment would likely be required to meet strict effluent quality requirements.

References

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Parker, Dr. Homer W. 1975. Wastewater Systems Engineering. Prentice-Hall, Inc., Englewood Cliffs, NJ.

FREEZE CRYSTALLIZATION

Description

Freeze crystallization is a general separations process used to remove pure components from solutions by crystallizing the materials to be removed. This process has been used for applications as diverse as organic chemical refining and fruit juice concentration, and is also suited for treating hazardous wastes.

The basic operation involved is the production of crystals by removing heat from a solution. Crystals produced in this manner invariably have very high purities. Once small, uniform crystals have been produced, they must be washed to remove adhering brine. The brine is recycled to the crystallizer, so that as much solvent as desired can be recovered. The pure crystals are usually melted in a heat-pump cycle, which further improves the energy efficiency of the process.

When one or more of the solutes exceeds its solubility, additional crystal forms are produced, but they are formed separately from each other and from the solvent crystals. Since in most waste applications the solvent is water, and ice is always less dense than the solution and the solutes usually more dense, it is easy to separate these crystals by gravity.

Applications

The process works on aqueous streams containing heavy metals, all types of dissolved organics, and radioactive materials. This technology can also be used to process the liquid stream from soil washing operations.

The process is economically and technically competitive on very contaminated streams. For example, wastes with heavy metals require concentration of 1,000 to 10,000 mg/l to be economically recoverable with freezing.

Advantages and Disadvantages

Freeze crystallization has several advantages for remediation and waste recovery applications. First, it is a very efficient volume reduction process, producing a concentrate that has no additional chemicals added to it - if disposal in a hazardous waste landfill, or incinerator destruction is required, this will reduce these costs substantially. When a large fraction of the solvent (usually water) is removed from a waste, the remaining impurities often begin to crystallize as well - they are often sufficiently pure to have by-product value for resale.

The main disadvantage of this process is its relatively high cost for treating streams with low concentrations of contaminants. The process is also relatively complex, requiring numerous pieces of equipment, compressors, heat exchangers, and pumps.

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GAMMA IRRADIATION

Description

This technology uses ionizing gamma radiation to decompose organic compounds. The media containing the organic constituents are exposed to a source of gamma radiation. The radiation excites the organic constituents to a higher energy state, which causes them to decompose. Gamma irradiation has been successfully applied to disinfection of sewage sludge. The process has been demonstrated to be effective for destruction of chlorinated hydrocarbons.

Applications

Gamma irradiation is applicable to disinfection of sewage sludge and destruction of organic constituents, particularly chlorinated hydrocarbons. Exposure of organic compounds to gamma radiation produces partially decomposed organic compounds as well as hydrogen, oxygen, and chlorine. Treatment of off-gases produced by the technology would be required. It is possible that some of the partially decomposed organics may be more toxic than the original constituents.

Some organics are not amenable to treatment by gamma irradiation. Treatability testing would be required prior to application of the technology in the field. The process has no reported effect on heavy metals or radionuclides.

Advantages and Disadvantages

Gamma irradiation is a proven technology for disinfection of sewage sludge. The process has also been demonstrated to be effective for destruction of some organic constituents, particularly chlorinated hydrocarbons. The process seems well suited for application to sewage sludge contaminated with halogenated organics. The process may also be used for treatment of water or sludges contaminated with halogenated organics and which may foster unwanted biological activity. It is expected that bench testing should be available for this technology. The results of bench testing will probably be representative of the effectiveness of the process.

The process appears limited in the scope of its applicability. The gamma irradiation process produces off-gas which will require treatment. It is not clear what destruction efficiencies are achievable or what the costs of the process are.

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HARDWICKIA BINATA BARK ADSORPTION

Description

Hardwickia binata bark was found to have good sorption capacity for mercury (II). Studies indicated that the sorption of Hg (II) increases as the pH increases and a contact time of two hours was found to be optimum.

Applications

Hardwickia binata bark adsorption treats aqueous waste containing mercury (II).

Advantages and Disadvantages

The presence of light metal ions interferes with sorption of mercury.

References

Deshkar, A M , S S Bokade, S S Dura 1990 Modified Hardwickia Binata Bark Absorption of Mercury (II) from Water Water Resources, 24 (8), pp 1,011 - 1,016

HOLLOW-FIBER SUPPORTED LIQUID MEMBRANES

Description

This technology uses a liquid extractant supported on hollow polypropylene fibers to extract ionic radionuclides from water. The extractant is then regenerated by using an aqueous solution of a complexing agent. This results in the concentration of the radionuclides into a much smaller volume of liquid.

Applications

Laboratory tests on Hanford, Washington site groundwater demonstrated the removal of uranium using bis(2,4,4-trimethylpentyl)phosphonic acid contained in the commercial extractant Cyanex 272 as the extractant. The water-soluble complexing agent 1-hydroxyethane-1,1-diphosphoric acid was used as the stripping agent.

Advantages and Disadvantages

This technology has the potential for treating radionuclide-contaminated water to significantly reduce the volume of material.

The technology has been demonstrated only on uranium under laboratory experiments.

References

Chiarizia, R, E P Horwitz, P G Rickert, K M Hodgson, 1989 Application of Supported Liquid Membranes for Removal of Uranium from Groundwater Report No 10NF-891013-4 Argonne National Laboratory

IN SITU AIR STRIPPING

Description

This process uses horizontal air injection wells installed below the aquifer and extraction wells located either above or in the upper portion of the aquifer. In effect, an in situ diffused air stripping column is constructed. Air introduced at the bottom of the aquifer diffuses through the aquifer and is extracted at the top. While passing through the aquifer, the air strips and removes the volatile organics.

Applications

This process would be applicable to shallow aquifers containing volatile organic contaminants.

Advantages and Disadvantages

This technology eliminates the need for an external air stripping tower. Additionally, the need for pumping the groundwater to the surface and disposing of the treated groundwater is eliminated.

The process produces a contaminated air stream that may require treatment. System costs are highly site-specific and the process may be difficult to control.

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IN SITU BIOREMEDIATION OF GROUNDWATER

Description

In situ aerobic biological treatment of groundwater involves the stimulation of biological growth in the contaminated zone in order to reduce the contaminant concentrations. Microorganisms that can use some or all of the contaminants as substrate will normally exist in a contaminated environment. The microorganisms are stimulated to increase their biological growth and consumption of contaminants through addition of an oxygen source and essential nutrients and micronutrients. Anaerobic processes also exist.

The aerobic in situ treatment system generally consists of injection wells for injecting an oxygen source and required nutrients and extraction wells for monitoring and recovering by-products. The most common oxygen source is dilute hydrogen peroxide. Inocula of acclimatized bacteria may be added as needed. The treatment efficiency is measured in terms of contaminant reduction, dissolved oxygen, and bacterial growth.

In situ treatment may also be carried out as an anaerobic process. This requires that anaerobic conditions are established in the contaminated zone. The operation of such a system is essentially the same as for the aerobic, except that no oxygen addition is involved. The anaerobic and aerobic in situ processes may also be combined and operated in series.

Applications

In situ biodegradation has been used for various applications such as gasoline spills and wood-treating wastes containing semivolatile and nonvolatile organics (U S EPA 1986c, Litchfield 1986). While it was previously thought that trichloroethylene (TCE) was only anaerobically degradable, recent in situ studies have demonstrated that TCE can also be treated aerobically in situ (Roberts et al 1989).

Even though most compounds can be biologically degraded, it should be noted that in situ treatment is dependent on other process-controlling factors such as geological and hydrological conditions.

Advantages and Disadvantages

The major advantages of in situ biological treatment are

- Can be carried out in place
- No sidestreams generated
- Only environmentally safe compounds are added
- Relatively inexpensive operation

Disadvantages include

- Level of cleanup generally less than for aboveground treatment trains
- May be difficult to control
- Difficult to treat broad mixtures of compounds

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ION EXCHANGE

Description

Ion exchange can be used for the removal of undesirable anions and cations from a wastewater stream (Eckenfelder 1989). Cations are exchanged for hydrogen or sodium and anions for hydroxyl ions. Most ion-exchange resins used in wastewater treatment are synthetic resins made by the polymerization of organic compounds into a porous three-dimensional structure. Functional ionic groups are usually introduced by reacting the polymeric matrix with a chemical compound containing the desired group. Exchange capacity is determined then by the number of functional groups per unit mass of resin.

Treatment of wastewater by ion exchange involves a sequence of operating steps. The wastewater is passed through the resin until the available exchange sites are filled and the contaminant appears in the effluent. At this point, the process is stopped and the bed is backwashed to remove dirt and to regenerate the resin.

Applications

One of the major applications of ion exchange is the removal of chrome from industrial plating streams. Other anions or cations from wastewater streams can be removed. Macroreticular resins are used for the removal of specific organic compounds such as chlorinated pesticides and aromatic hydrocarbons. This technology has been used successfully for the remediation of heavy metals and uranium from wastewater and groundwater at the Hanford (Weiss 1990) and Savannah River Sites (Sferrazza 1990).

Advantages and Disadvantages

One of the advantages of ion exchange is that the removed product from the wastewater stream can be recovered and reused or concentrated for more controlled disposal.

Other ions within a waste stream can compete with the ion of interest to remove in the exchange process, thus reducing the capacity. For instance, iron in groundwater competes for the exchange of more hazardous ions like chromium or uranium.

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OXIDATION/REDUCTION

Description

The chemical reduction-oxidation (redox) process involves a change of the oxidation state of the reactants, one is increased while that of the other reactant is reduced. Common oxidizing agents include ozone, hypochlorite, and chlorine. Common reducing agents include sodium borohydride, sulfur dioxide, and ferrous sulfamate (U.S. EPA 1985, 1986a).

The purpose of redox treatment of inorganic compounds (excluding heavy metals) in water is generally to break a compound into simpler, less toxic constituents. Examples are the conversion of sodium cyanide to carbon dioxide and nitrogen using alkaline chlorination and the conversion of ammonium to nitrogen and water using sodium nitrite (Marin et al. 1979).

The use of redox treatment of waste streams containing metals is typically required to enhance a subsequent precipitation step. The redox reaction is used to adjust the metal to an oxidation state that will result in the formation of an insoluble metal salt precipitate that can then be physically removed from the bulk of the aqueous waste stream.

An example is the use of sulfur dioxide to reduce hexavalent chromium to trivalent chromium, which is then precipitated as chromous hydroxide. In general, the use of redox in conjunction with precipitation for the removal of heavy metals is a well established water treatment method.

Applications

A typical redox process for removal of cyanide involves conversion of cyanides to cyanates with a 15 percent solution of sodium hypochlorite at a pH > 10. The cyanates are then further oxidized to N_2 and CO_2 with the sodium hypochlorite solution at pH 8.5. Complete oxidation takes approximately 10 minutes (Marin et al. 1979, EPA 1980). This type of process is common for treatment of electroplating rinse water.

Reduction of hexavalent chromium to its trivalent state followed by precipitation is a standard process step for treating chromium-bearing aqueous wastes. The solution pH is first adjusted to a pH of 2 to 3 by addition of hydrochloric or sulfuric acid. A reducing agent, typically sulfur dioxide or sodium metabisulfite, is then added. After the reaction is completed, the pH is adjusted to 7.5 to 8.5 using lime or caustic. At this pH, chromium hydroxide has its minimum solubility and precipitates (Lanouette 1977).

The use of redox reactions for the removal of trace quantities of uranium and transuranic elements from groundwater has not been demonstrated. Processes for recovery and purification of uranium and transuranic elements, however, rely heavily on adjustment of oxidation states. These processes include

precipitation as well as acid and solvent extraction. The separation of plutonium from cerium by extraction with tributyl phosphate (TBP) requires that the plutonium be oxidized to the tetravalent state without oxidation of cerium to its tetravalent state. Similarly, the separation of plutonium from uranium requires that the plutonium be trivalent and uranium hexavalent (Benedict et al 1981). Process solutions typically contain transuranic elements in concentrations orders of magnitude above those required to meet discharge limits.

The oxidation states and solubilities of uranium and transuranic elements at trace concentrations in groundwater have been studied by several researchers in recent years (Nitsche et al 1988, Kim et al 1988, Nash et al 1988, Cleveland et al 1985). In general, they found Pu(V) and Pu(VI) to be the oxidation states of the soluble plutonium species. Presumably, plutonium solubility could be reduced by reduction to Pu(III) or Pu(IV). The solubility is enhanced by the presence of carbonate and fluoride, which form complexes with the plutonium. Americium solubility is controlled mainly by the formation of radiocolloids.

Advantages and Disadvantages

The use of redox processes has the advantage that often inorganic contaminants may be transformed into less hazardous forms. The ability to adjust oxidation states of metals is advantageous and in some cases necessary for a subsequent treatment process, such as precipitation. A disadvantage of the use of chemical redox reactions is undesirable side reactions. These include the reduction or oxidation of organics and the production of chlorinated organics if the selected process is chlorination (Rice and Gomez-Taylor 1985). The process will also produce a sludge that requires further treatment or disposal.

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Technology Review No 135 Noyes Data Corporation pp 489-493

POTASSIUM FERRATE PRECIPITATION (TRU CLEAR™)

Description

This is a proprietary process being developed by Analytical Development Corporation. The process is used for the removal of trace levels of alpha-emitting transuranic (TRU) elements from water.

The technology is based on ferrate ion (FeO_4^{2-}) chemistry with TRU-removal accomplished by proprietary chemical additives into specific formulations for specific wastewaters. Ferrate chemistry has been studied for many years, but its commercial application has not occurred due to the inability to manufacture significant quantities of the material for large-scale use.

The novel ferrate chemistry which is used by this technology operates via a degradation chemical reaction in which the strongly oxidizing ferrate ion reacts with water to form an insoluble hydrated ferric oxide, hydroxide ions, and oxygen gas.



The rate of this reaction is catalyzed by trace metal ions which may be present in solution. In the presence of organic or inorganic reducing agents, the rate of degradation and its stoichiometry can be influenced radically as well. The reaction mechanisms discovered to date during investigation of ferrate chemistry and application indicate a possible violation of equilibrium solubility behavior as it is understood today. The experimental results indicated that transuranic metal elements can be removed using this chemistry to lower concentrations in solution than can be predicted by equilibrium solubility constants which are empirically measured. It is believed that several mechanisms are operating simultaneously in the system which contribute to the overall removal characteristics of the technology, including localized, kinetically controlled reactions. These mechanisms are being investigated presently in conjunction with the engineering development of the technology. The precipitative removal of transuranic elements from wastewater to unprecedented low concentrations is the total effect of these mechanisms and is not predictable by standard analysis.

Applications

The process is used for removing uranium and transuranic elements such as plutonium and americium from wastewaters. The process uses conventional precipitation and clarification equipment.

Advantages and Disadvantages

This technology may offer the ability to remove radionuclides to lower levels than achievable with conventional precipitation processes. It is also reported to produce much less sludge than conventional processes.

The primary disadvantage is that the process is based on a proprietary chemical, which would have to be purchased from a single supplier.

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POWDERED ACTIVATED CARBON

Description

The powdered activated carbon treatment (PACT) process incorporates biodegradation and physical adsorption to remove organic constituents from an aqueous stream. The reaction is carried out in an aeration basin. Powdered activated carbon added to the aeration basin adsorbs organics from the wastewater stream and acts as a substrate for microorganism growth. Non-biodegradable components remain adsorbed on the powdered activated carbon. A clarifier is used to separate treated water from spent powdered activated carbon and biomass. The powdered carbon is regulated until its adsorptive capacity is reached after which it is either regenerated or disposed of.

Applications

The process is applicable to aqueous streams with organic constituents concentrations ranging from 50 to 4,000 mg/l for large systems and up to 10,000 or 15,000 mg/l for small systems. Most organic constituents will be amenable to either biotreatment or adsorption onto the powdered activated carbon. PACT has been shown to reduce chemical oxygen demand by 93.5% and biochemical oxygen demand by 99.5%. Bench testing will be required to determine whether similar reduction efficiencies can be achieved for specific applications.

PACT is not applicable to treatment of heavy metals or radionuclides. While PACT is not directly applicable to contaminated soils, it may be possible to combine the process with soil washing or similar technologies.

Advantages and Disadvantages

The primary advantage of PACT is its applicability to a broad variety of organic constituents. It is commercially proven technology and is readily available. Vendor equipment is available for on-site regeneration of the powdered activated carbon. Bench testing is expected to be readily obtainable.

One potential disadvantage of PACT is that it may not remove some organic constituents to the degree necessary to achieve ARARs.

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Wagner, K, et al 1986 Remedial Action Technology for Waste Disposal Sites 2nd edition Pollution
Technology Review No 135, pp 558-559

PURE OXYGEN ACTIVATED SLUDGE

Description

This technology represents a modification of conventional activated sludge treatment in which pure oxygen is used instead of air. This requires the use of special equipment for extracting oxygen from ambient air. This technology offers potential advantages in performance and economics, which must be evaluated on a case-by-case basis.

Applications

This process is applicable to wastewaters containing high concentrations of biodegradable organics. However, chlorinated organics are not effectively treated.

Advantages and Disadvantages

Advantages and disadvantages are basically the same as for conventional activated sludge. Additional treatment would still be required to achieve low levels of organics in the treated effluent.

References

Rogoshewski, P., H. Bryson, and K. Wagner. 1983. Remedial Action Technology for Waste Disposal Sites. Noyes Data Corporation, Park Ridge, NJ.

SOLAR

Description

A system that uses solar energy to destroy hazardous organic wastes is being developed by VEDA Inc of Alexandria, Virginia. The heart of this system is an array of sun-tracking mirrors as heliostats, referred to as a unified heliostat array. Each heliostat concentrates and reflects the sun's radiant energy to a windowed reactor vessel. The heat and UV radiation provided by the unified heliostat array are used to destroy the organic contaminants.

A system for processing PCB or dioxin contaminated soil includes a desorption reactor, which heats the soil to 750°F. The high temperature vaporizes the organic contaminants from the soil. The heat for the desorption reactor is provided by cooling air from the windowed reactor.

The vaporized contaminants from the desorption reactor are injected into the windowed reactor where they are irradiated through a quartz window with concentrated solar energy from the unified heliostat array. The reactor temperature is maintained at 1,300°F (700°C) and is controlled by air flow around the reactor's ceramic liner. Inside the windowed reactor, organic compounds are decomposed by the high temperature and UV radiation. Some of the resulting exhaust gas is recirculated through the desorption reactor to provide additional heat needed to raise the temperature of the contaminated soil. The remainder of the exhaust gas is treated in a scrubber to remove hydrogen chloride, sulfur dioxide, and particulates before it is discharged to the atmosphere.

Applications

This process is applicable to soils and sediments that are contaminated with volatile and semivolatile organics. The process may also be applied to aqueous streams.

Advantages and Disadvantages

The process offers high destruction efficiencies for organic contaminants. Efficiencies as high as 99.9999% have been achieved.

The system is not commercially available. However, a prototype system designed to process 500 pounds of contaminated soil per hour is being developed. Additional research is in progress to determine the temperature and condition necessary to volatilize and desorb PCBs and dioxins from soil.

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SOLAR PHOTOCATALYTIC

Description

This is a proprietary process developed by Sandia National Laboratories and the Solar Energy Research Institute. It provides solar-driven detoxification of contaminants using titanium dioxide as a catalyst.

Applications

The process is used to destroy organics in contaminated groundwater and surface water. Experiments have successfully demonstrated its effectiveness on trichloroethylene (TCE).

Advantages and Disadvantages

This process, when fully developed, may offer significant economic advantages due to its low power requirements.

This process, however, is still in the developmental stage and more information is needed to evaluate effectiveness and economics for specific applications.

References

DOE Supports Effort to Develop Solar Process to Detoxify Organics 1991, May 2 HazTECH News
V 6, no 9

SOLVENT EXTRACTION

Description

Solvent extraction is used to remove organic constituents and some heavy metals from water, soil, or sludge. A solvent is chosen in which the contaminants of concern are soluble. The chosen solvent and the matrix to be treated are mutually insoluble. When the solvent and the waste are contacted, the contaminants of concern transfer from the waste matrix to the solvent. The waste and solvent are then separated. At this point, the waste matrix may be disposed or treated further, as appropriate. The solvent may be regenerated for reuse.

Applications

Solvent extraction is applicable to a wide variety of constituents. However, most solvents will be effective for particular types of constituents and will not be effective for other types. In addition, it is possible that some constituents may not be amenable to solvent extraction. Each system must be tested to select appropriate solvents.

Solvents containing extracted constituents should be regenerated, if possible, to allow economical treatment. This process does not destroy the extracted constituents. Further treatment of extracted constituents may be required prior to ultimate disposal.

The process is not applicable to constituents which may not be removed from the solvent during regeneration. Matrix conditions, such as pH, or the presence of surfactants or emulsifiers, may alter the effectiveness of the process.

Advantages and Disadvantages

The primary advantages of solvent extraction are its applicability to a wide range of contaminants and the widespread use of solvent extraction in industrial applications. Solvent extraction may be readily bench tested.

Costs of solvent extraction are higher than for absorption or stripping methods. In most cases, solvent extraction will be effective for a limited number of the constituents in the waste matrix, necessitating further treatment of the waste. Recovered contaminants will require treatment prior to disposal.

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STEAM STRIPPING

Description

Steam stripping involves injection of steam into a solution to volatilize the organic compounds in the solution. It can be operated as a batch or continuous process.

The batch process involves a batch still, an overhead vapor line, a condenser, a condensate receiver, and a gravity separator. Steam, injected through a perforated pipe in the still, provides the heat for vaporization of the waste. Vapor is condensed and collected as a liquid in the condensate receiver. Liquids with similar boiling points and different densities may be separated by gravity separation in the condensate receiver (U S EPA, 1987c).

In continuous steam stripping, waste flows down the column while steam flows up as in air stripping. The column is designed to promote transfer of contaminants to the gas phase by causing effective heat transfer to the waste, by creating turbulence in the waste, and by providing a large waste surface area. Different liquid-vapor equilibria exist at various heights in the column, with the highest relative concentration of the most volatile component being on the top (Blaney, 1986), however, all volatiles are swept out together in steam stripping.

Applications

Steam stripping is able to strip compounds with lower volatility than those removed by air stripping. The technology is reported to be effective for removal of high concentrations of organics, ranging from 1 to 20 percent (U S EPA, 1986a). Volatile organics, as well as semi-volatiles such as phenols, ketones, and phthalates, are good candidates for removal by steam stripping. Steam stripping is currently used at some commercial and industrial facilities to treat RCRA-spent solvent wastewaters (Turner, 1989). Hydrogen sulfide and ammonia can also be removed by this process (U S EPA, 1987c). Steam stripping is reported to be capable of removing over 99 percent of ammonia in high strength industrial wastes (Wickramanayake et al, 1989).

Advantages and Disadvantages

Steam stripping is a well demonstrated technology and commonly used in industry. As compared to air stripping, it may be used to treat less volatile compounds. However, the process generates a concentrate that requires treatment or disposal if recycling of the concentrate is not an option. This process is also expensive to operate, and is cost effective only when a source of waste heat or low cost fuel for producing steam is available.

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SUBMERGED AEROBIC FIXED FILM REACTOR

Description

The submerged aerobic fixed film reactor is a biodegradation system used for destruction of organic compounds in aqueous media. The process uses a bioreactor packed with plastic media which acts as a support for a film of bacterial growth. The packing is completely submerged in the bioreactor. Air or oxygen is pumped into the bioreactor to maintain aerobic conditions. In addition to oxygen, it may be necessary to add nutrients to the bioreactor for some applications. The submerged aerobic fixed film reactor requires less space than an aeration basin. This is due to the greater surface area provided by the bacterial film, and to the higher oxygen loading provided to the microorganisms.

Applications

The process is applicable to aqueous media contaminated with organic constituents which are amenable to biodegradation. The submerged aerobic fixed film reactor has been shown to be effective for relatively low concentrations in the influent stream. This is an advantage over other bioreactors, such as rotating biological contractors or aeration basins, which are not effective for low concentrations of organic contaminants. It may be necessary to combine the process with treatment of the bioreactor effluent by granular activated carbon for adsorption of non-biodegradable organic constituents.

Submerged aerobic fixed film technology is not applicable to radionuclides or heavy metals. Some metals have a toxic effect on the bacterial growth and must be avoided. Certain halogenated organic compounds are not readily destroyed by strictly aerobic biodegradation and are not amenable to treatment by this technology.

Advantages and Disadvantages

The primary advantages of the submerged aerobic fixed film reactor are applicability to a broad range of organic constituents, effectiveness for treatment of relatively low contaminant concentrations, and relatively low capital and operating costs.

The technology is not effective for all organic contaminants, it may be necessary to combine the process with a treatment technology for the bioreactor effluent.

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NJ

SUPERCritical WATER OXIDATION

Description

Supercritical water oxidation uses oxygen dissolved in water above its critical point to oxidize organic compounds. Oxygen, from ambient air or from an oxygen source, is added to the water containing the organics to be treated. The water temperature and pressure are then raised above the critical point and rapid oxidation takes place. The heat released during oxidation is often sufficient to sustain the reaction. If the heat release is not sufficient, energy in the form of supplemental heat or organic compounds may be added to the water. Salts formed in the oxidation process generally precipitate out of solution. After the treated water is cooled and the pressure is released, off-gases are released which may require treatment.

Applications

Supercritical water oxidation may be used to treat a variety of organic constituents, though it is less effective for halogenated compounds. Some work has been done with catalysts for treatment of halogenated compounds, however, the technology remains unproven for catalytic applications. The organics are partially oxidized to organic acids or completely oxidized to carbon dioxide and water. Sulfur-containing compounds are oxidized to sulfate salts. Nitrogen-containing compounds are reduced to elemental nitrogen. Oxidation temperatures are not sufficient for generation of nitrogen oxides (NO_x).

For many compounds, oxidation is not complete. Organic and/or fatty acids will remain as by-products of the oxidation process. In most cases, it would be expected that the toxicity of the organic compounds will decrease. Aromatic compounds are less easily oxidized by the supercritical water oxidation process.

The technology is not applicable to or economically feasible for treatment of water containing organic compounds in low part per million concentrations. The process is not applicable to radionuclides or heavy metals.

Advantages and Disadvantages

The primary advantage of supercritical water oxidation is that a variety of toxic organic constituents may be destroyed by low-temperature oxidation. Acid gases are easily controlled. The technology is proven at the commercial scale and equipment is readily available. Treatability testing may be conducted at the bench scale.

The primary disadvantages of supercritical water oxidation are that the technology does not effectively treat some organic constituents and it has high initial and operating costs. Some organic compounds

are not completely oxidized, partially oxidized compounds may be more toxic than the original compounds in some cases. The technology may not provide for sufficient removal of some compounds which may be present in low concentrations. The requirements to prevent corrosion of the system and plugging and plating out of metals is also a disadvantage. The system operates under high pressure which is a potential safety concern.

References

U S EPA 1988, September Technology Screening Guide for Treatment of CERCLA Soils and Sludges
NTIS, PB89-132674

ULTRAFILTRATION

Description

This process uses special membrane material in equipment very similar to that used for reverse osmosis. The membrane material used has a much larger pore size than reverse osmosis membranes. Operating pressures are much lower, typically 50 to 100 psi versus 400 psi for reverse osmosis.

The most recent technology is based on a cross-flow element design. In this process, the influent, or feed stream, is separated into two effluent streams: the "permeate" or clean stream, and the "concentrate" which retains all of the suspended solids rejected by the membrane. Only the permeate actually passes through the membrane. The feed and concentrate streams flow parallel to the membrane surface, resulting in the term "cross-flow". In this type of element, the solids are swept away with the concentrate, eliminating or greatly reducing the potential for the element to plug.

Applications

The process is applicable to wastewaters that contain contaminants in particulate form. For example, plutonium is often present as particulates that can be removed by this process.

Dissolved metals and radionuclides can also be removed by this process if they are first precipitated in a pretreatment process step.

Advantages and Disadvantages

This process offers the advantage of improved removal efficiencies over conventional filtration. The process is easily automated, and pre-engineered package systems are readily available.

The primary disadvantage is relatively higher costs over conventional filtration.

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Crossflow Micro-Filtration System Installed to Remove Pesticides, Metals from Wastewater 1991, March 21 HazTECH News V 6 no 6

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U S EPA 1988 The Superfund Innovative Technology Evaluation Program Technology Profiles EPA/540/5-88/003 November 1988

UV/CHEMICAL OXIDATION OF ORGANICS

Description

Chemical oxidation is used to degrade hazardous organic materials to less toxic compounds. A number of different chemical oxidation processes exist for treatment of organic contaminants. These include chlorination, ozonation, and treatment by a combination of UV radiation, and ozone, and/or hydrogen peroxide (U S EPA 1985, 1986a, Wentz 1989)

Chlorination In this process chlorine is added to water to oxidize both organics and inorganics. Chlorine, which is added in its elemental form (gas), chlorine dioxide gas, or hypochlorite salt, is a strong oxidizing agent in aqueous solutions. The primary use of chlorination has been for disinfection of drinking water. A potential disadvantage of this process is that the chlorine may form potentially toxic chlorinated by-products.

Ozonation Ozone is a strong chemical oxidant that has been used for purification, disinfection, and odor control of drinking water. Ozone is generated from air or oxygen and is applied by bubbling the gas through the water being treated. Ozone efficiently breaks down some easily oxidizable organics, but has generally been shown to be an ineffective oxidant for halogenated organics at reaction times and concentrations normally used in drinking water treatment. Complete oxidation of organic species to carbon dioxide and water may require high ozone dosage and long contact times. If inorganics, such as iron, are present, their oxidation may inhibit the destruction of organics.

UV/Ozone/Hydrogen Peroxide The use of ultraviolet (UV) radiation in combination with ozonation has been found to catalyze the oxidation process and is now in common use. This form of treatment is accomplished by contacting the ozone and the contaminated water in a closed reactor in the presence of UV light. The combination of UV and ozone treatment makes it possible to oxidize compounds that would not be oxidized by ozone treatment only. UV radiation causes destruction or weakening of the chemical bonds in the organic compounds, thereby acting as a catalyst for the oxidation process. Hydrogen peroxide can be used in combination with UV light as an alternative to ozone, or all three may be combined.

Complete oxidation of organics results in the formation of carbon dioxide and water. In waste treatment, complete oxidation of all the contaminants is difficult and expensive to achieve, so a variety of low molecular weight organics are formed in the process. Since various degrees of oxidation occur in complex mixtures, it is important that the system be designed for removal of selected target contaminants. A thorough characterization of by-products is necessary.

Applications

Chemical oxidation processes have been reported for dilute waste streams containing aldehyde, mercaptans, phenols, benzidine, unsaturated acids, and some pesticides (Kiang and Metry 1982)

The UV/Ozone/Peroxide system as marketed by ULTROX International has been used for pilot-scale and full-scale treatment of a variety of organic contaminants (Fletcher 1987, Barich 1990) In a pilot-scale test, the system was found to reduce trichloroethylene (TCE) from 200 ug/L to 2.6 ug/L and carbon tetrachloride from 10 ug/L to 2.9 ug/L. The ULTROX system has been used full-scale for treating 200,000 gallons of tetrahydrofuran-contaminated groundwater. The contaminant concentrations were reduced from 5,000 ug/L to nondetectable levels. Groundwater contaminated with TCE, tetrachloroethylene (PCE), and 1,1,1-trichloroethane at 470, 96, and 166 ug/L, respectively, was treated to below drinking water standards in pilot studies. Pilot studies were also conducted and demonstrated the reduction of polychlorinated biphenyl (PCB) concentrations from 50 ug/L to less than 1 ug/L.

Similar systems are manufactured by Solarchem (Ontario, Canada) and Peroxidation Systems, Inc (Gardenia, California)

Advantages and Disadvantages

Chemical oxidation of organic contaminants has the advantage that the contaminants are destroyed in the process. On a cost basis, UV/ozone/peroxide treatment is competitive with GAC treatment. Natural organics and inorganics may interfere with the oxidation process and increase the oxidant requirements. Undesirable organic by-products may also be formed.

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pp 15 16 pp 81-82

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Advantages and Disadvantages

A primary advantage of this process is that it destroys the applicable contaminants rendering them harmless to the environment. It is effective on a wide range of contaminants and may offer economic advantages in specific cases.

The process is complex and requires high operating temperatures and pressures. Expensive equipment is required, as well as highly trained operators.

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APPENDIX C
TECHNOLOGY DATA SUMMARIES FOR SOIL/SEDIMENT
TECHNOLOGIES REVIEWED IN THE ANNUAL REPORT

APPENDIX C
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AEROBIC BIOLOGICAL REACTOR

Description

The aerobic biological reactor is a biodegradation system used for destruction of organic compounds in an aqueous media. The process uses a bioreactor packed with plastic media which acts as a support for a film of bacterial growth. The packing is completely submerged in the bioreactor. Air or oxygen is pumped into the bioreactor to maintain aerobic conditions. In addition to oxygen, it may be necessary to add nutrients to the bioreactor for some applications. The submerged aerobic fixed film reactor requires less space than an aeration basin. This is due to the greater surface area provided by the bacterial film, and to the higher oxygen loading provided to the microorganisms.

Applications

The process is applicable to aqueous media contaminated with organic constituents which are amenable to biodegradation. The submerged aerobic fixed film reactor has been shown to be effective for relatively low concentrations in the influent stream. This is an advantage over other bioreactors, such as rotating biological contractors or aeration basins, which are not effective for low concentrations of organic contaminants. It may be necessary to combine the process with treatment of the bioreactor effluent by granular activated carbon for adsorption of non-biodegradable organic constituents.

Submerged aerobic fixed film technology is not applicable to radionuclides or heavy metals. Some metals have a toxic effect on the bacterial growth and must be avoided. Certain halogenated organic compounds are not readily destroyed by strictly aerobic biodegradation and are not amenable to treatment by this technology.

Advantages and Disadvantages

The primary advantages of the aerobic biological reactor are applicability to a broad range of organic constituents, effectiveness for treatment of relatively low contaminant concentrations, and relatively low capital and operating costs.

The technology is not effective for all organic contaminants, it may be necessary to combine the process with a treatment technology for the bioreactor effluent.

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ANAEROBIC REDUCTIVE DECHLORINATION

Description

Most of the environmental contamination by chlorinated organics is in the form of complex commercial mixtures containing numerous compounds with varying degrees of chlorination. Biodegradation of this large number of distinct compounds therefore requires broad enzymatic specificity. Additionally, chlorinated organic materials frequently resist microbial degradation. Although these complex chlorinated mixtures are difficult to degrade, the aerobic bacterial degradation of chlorinated organics has been demonstrated in the laboratory.

Applications

This process is applicable to soils, sediments, and aqueous streams contaminated with chlorinated solvents.

Advantages and Disadvantages

This process would completely destroy the chlorinated organic compounds, converting them to cell material, carbon dioxide, and water.

This process is currently in the early development stage, and more research is required to evaluate effectiveness, implementability, and economics.

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ANAEROBIC BIOLOGICAL ACTIVATED CARBON PROCESS

Description

The anaerobic biological activated carbon (AnBAC) technology is being developed to treat wastes containing high concentrations of organics. The process uses a granular activated carbon bed operated under anaerobic conditions. The carbon serves to both adsorb and immobilize organic contaminants and support the microorganisms that feed on the contaminants. The process has been demonstrated at the bench scale and pilot scale for treating wastes containing high concentrations of phenol and formaldehyde.

Applications

This process is applicable to treating aqueous streams containing high concentrations of biodegradable organics.

Advantages and Disadvantages

This technology destroys toxic organics, rendering them harmless to the environment. The process may offer an economic way to treat concentrated waste streams.

The process is not commercially available and requires more study to assess effectiveness, implementability, and economics. Additional treatment would probably be required to meet stringent effluent quality criteria. This technology requires long startup periods before the biological process begins to effectively degrade the contaminants.

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B E S T ® PROCESS

Description

Resources Conservation Company's Basic Extractive Sludge Treatment (B E S T ®) process technology was invented during the 1960s by Boeing Company to process waste generated during the manned space flights. Since then, Resource Conservation Company (RCC) of Bellevue, Washington, owner of the B E S T ® patents, has developed the process from laboratory-scale testing through prototype full-scale operation. The process has been tested on municipal wastewater sludge, petroleum refinery wastes, PCB-contaminated soils and sediments, and oily hazardous wastes at regulated sites.

The process is configured to exploit the unique solvent properties of triethylamine (TEA). Triethylamine easily breaks the oil/water emulsions that cause major problems in some separation processes. At or below 20°C, TEA is completely miscible. This "inverse miscibility" property is used by letting the oil and water components of a waste combined with the TEA to form a homogeneous, single-phase extraction mixture of oil/water/TEA. When oil/water emulsion is broken, bonded water is liberated and the bound particulates are released from the solution. The extraction efficiency of the system is enhanced because the amine solvent is able to achieve close contact with all components of the waste.

Before the extraction process is begun, feed material must be screened and pH adjusted to an alkaline condition. The feed is then introduced into a mixing tank and combined with TEA chilled to temperatures below the miscibility point (<20°C). At that temperature, a single liquid phase is formed and the solid material settles out. The mixture is agitated until equilibrium is reached, then the solids are removed from the solution either by filtration or centrifugation. Multiple extraction stages may be required to achieve contamination removal target levels.

The liquid fraction, a single-phase oil/water/TEA mixture, is heated to a temperature of 20°C and two distinct phases form: an aqueous phase, and an organic phase made up of oil and TEA. The phases are separated by decantation into an oil/TEA phase and heavier water phase. The oil/TEA phase contains virtually all the oily material and organic contaminants. The TEA is recovered from the oil/TEA fraction by flash evaporation and steam stripping. Residual TEA is removed from the water layer by steam stripping. Recovered TEA is chilled and recycled for use in the process system.

The separated solids are returned to the feed tank for additional extraction with TEA. When extraction has been completed, solids are centrifuged or filtered and then dried to remove residual TEA and water.

Oil, water, and solids are produced by the process. Ideally, the product water can be conveyed to a water treatment facility for minimal treatment and discharged to the environment. The oil fraction may be reused as fuel, recycled, or destroyed if the organic contaminant levels in the oil are too high. The solids fraction may be returned to the site or sent to a disposal facility.

Applications

The B E S T® process can be used to treat soils and sediments contaminated by a wide range of organic compounds, including PCBs

Advantages and Disadvantages

The process can achieve removal efficiencies that exceed 98 percent for organic compounds. However, the process is complex and its capital and operating costs could be high.

Processed material sizing requirements may limit processing applications or add significantly to processing costs since oversized material requires pretreatment.

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US EPA. September 1988. Technology Screening Guide for Treatment of CERCLA Soils and Sludges. EPA/540/2/88/006

CF SYSTEMS ORGANIC EXTRACTION

Description

CF Systems Corporation has developed a solvent extraction process that uses critical fluids and liquified gases such as carbon dioxide, propane, or other light hydrocarbons at high pressure to separate and recover oils from refinery sludges and to extract hazardous organic compounds from wastewater, sludge, sediment, and soil. The process typically uses propane on contaminated soil and sludge and carbon dioxide to treat wastewater. These solvents provide high extraction efficiencies, evaporate readily from extracted organic material, and have high solubilities for most organic priority pollutants. They are inexpensive, readily available, nontoxic, and easily separated and retrieved from the process products.

The extraction process consists of four basic unit operations: solvent extraction, phase separation, solvent recovery, and filtration. Prior to processing, the particle size of the feed materials must be reduced, typically to at least 5 mm diameter, and the feedstock must be pumpable. To process hazardous soil or sludge, the waste is slurried and fed into the top of the extractor. The solvent (propane), condensed by compression, flows upward through the extractor. The condensed solvent contacts the waste slurry, rapidly dissolves the oils, and extracts most of the organic contaminants from the water. When extraction is complete, the clean water/solids mixture is withdrawn from the bottom of the extractor. The contaminated solvent is discharged from the top of the extractor and passed through a pressure reduction valve to a separator. In the separator, the extraction solvent is vaporized, recompressed, and recycled to the process as fresh solvent. The extracted organic contaminants are recovered from the separator for treatment in a separate process. Several stages of extraction and decanting may be required to attain a given cleanup level. Reportedly, up to 90 percent of the solvent is recycled in the system, the remaining 10 percent retains the extracted contaminants.

Applications

The process can be used to remove a wide variety of organics from soils and sediments. The process was demonstrated at pilot scale for the EPA's SITE program and shown to be capable of removing PCBs from contaminated sediments. A commercial-size unit has been constructed to treat refinery sludges from a refinery in Texas.

Advantages and Disadvantages

The process offers low operating costs due to the use of inexpensive recoverable solvents. The process does not require high operating temperatures.

The primary disadvantage relates to materials handling. Since the waste must be slurried before process, the process may be applicable to wastes with too broad a range of particle sizes. If larger particles are screened out prior to processing, disposal of the untreated reject material may add to process costs. Also, the process equipment may be costly because of the high operating pressures required and the design safety features needed when using a flammable solvent. In addition, uncontrolled solvent losses raise safety concerns, and controlled solvent release by flaring may require a permit.

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CHEMICAL STABILIZATION

Description

Stabilization usually involves the addition of a chemical reagent to react with the contaminant producing a less mobile or less toxic compound. It is generally used with a solidification process to immobilize a waste. Two major forms of solidification/stabilization, pozzolanic-based and cement-based, have been used extensively to treat hazardous waste (U.S. EPA 1985, 1986d).

Pozzolanic-Based This solidification method used materials that form a solid mass when mixed with hydrated lime. Pozzolanic materials include diatomaceous earth, blast-furnace slag, ground brick, and some fly ashes. After mixing of the waste and pozzolan, hydrated lime is blended into the mixture. The resulting moist mixture is packed into a mold and allowed to cure.

Cement-Based Cements are often used as binding agents, along with pozzolanic materials, to improve the strength and chemical resistance of solidified waste. The types of cement used for solidification can be selected to emphasize a particular cementing reaction.

Applications

Solidification/stabilization is being used for low-level radioactive and RCRA mixed wastes at the Hanford nuclear reservation (Sferrazza 1990). After mixing the wastes with portland cement, fly ash, and clay, the cemented wastes are poured into specially constructed near-surface concrete vaults that isolate the cement product from the environment (Collins 1988). The combination of waste solidification and placement in concrete vaults is designed to contain the waste materials for at least 10,000 years.

Record of Decision (ROD) documents for at least seven Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites have identified solidification/stabilization as the remedial technology of choice for immobilization of heavy metal contaminants. These sites include the Selma Pressure Treating Company, CA, Flowood, MS, York Oil, NY, Chemtronics, NC, Bailey Waste Disposal, TX, Mid-State Disposal Landfill, WI, and Love Canal, NY.

Various solidification/stabilization techniques have been used at DOE sites throughout the United States. The 513 Solidification Unit at Lawrence Livermore National Laboratory uses cement, Envirostone™, Petroset™, and Aquaset™ to solidify liquid wastes. The Los Alamos National Laboratory uses an in-drum solidification technique for immobilization of TRU solid and liquid wastes. Plutonium precipitation sludge is immobilized in-drum at Mound using portland cement. The Oak Ridge Facility uses a fly ash cement to immobilize a treatment pond sludge containing uranium, chromium, nickel, cadmium, and technetium. Portland cement is used to immobilize waste sludge in Rocky Flats pondcrete and saltcrete processes (Sferrazza 1990).

Advantages and Disadvantages

Solidification/stabilization is a well established process for reducing the mobility and toxicity of hazardous waste. Solid wastes containing radioactive contaminants are well suited for this process as it contains and reduces the mobility of the radioactive materials. Organic compounds, if present, often interfere with the desired solidification and stabilization process.

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FENTON'S REAGENT DECOMPOSITION

Description

Fenton's reagent has the ability to decompose varieties of organic compounds. Fenton's oxidation involves reaction of ferrous iron with hydrogen peroxide to generate hydroxyl radicals. The value of the reaction rate constant k is 76 L/mol-sec.

Applications

Fenton's reagent has been shown to be effective for the remediation of PCBs/PCE-contaminated soils.

Advantages and Disadvantages

A disadvantage of Fenton's reagent decomposition is the possibility of the formation of intermediate products that may need treatment.

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FLUIDIZED BED INCINERATION

Description

Fluidized bed incineration uses air blown upward through the combustion zone of the incinerator to fluidize a bed of sand or other granular media. The result is a highly turbulent combustion zone with a large heat capacity. Waste material, including solids, liquids, sludges or gases, is injected directly into the fluidized bed. Volatiles are driven out of the waste and oxidized. Inerts accumulate in the fluidized bed. Bed material is occasionally drained from the fluidized bed to maintain an acceptable pressure drop across the bed. The operating temperature of the fluidized bed is limited by the softening point of the inerts in the feed material. If the operating temperature exceeds the softening point, agglomeration of bed media into particles too large to fluidize may occur. Combustion efficiency suffers when bed agglomeration occurs to an appreciable degree.

Applications

Fluidized bed incineration may be applied to organics and some inorganics in water, sludges, solids or gases. Treatment of off-gases for control of emissions is required. Wastes containing metals may require treatment of drained bed media to immobilize the metals.

The process is not applicable to wastes with low softening points. Fluidized bed incineration has a neutral effect on metals and non-volatile radionuclides, though the technology has been used for volume reduction of low level radwastes composed primarily of combustible material (such as paper or graphite). The technology is not applicable to materials containing volatile or semivolatile metals.

Advantages and Disadvantages

Fluidized bed incineration is applicable to a wide variety of organic constituents. It is a well understood, commercially available technology. The high degree of turbulence in fluidized bed incinerators allows them to achieve the same degree of combustion efficiency with lower operating temperatures. Because of this, fluidized beds frequently have lower operating costs than other incinerators under similar conditions.

The technology has a neutral effect on most inorganics. It is not applicable to volatile or semivolatile metals nor to wastes with low softening points. Operating costs are moderately high because of the power required to fluidize the bed media. Wastes with little or no heating value require addition of supplemental fuel. Pilot testing is readily accomplished through a number of vendors, but bench testing is uncommon and of questionable value.

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US EPA September 1989 Forum of Innovative Hazardous Waste Technologies Domestic and International Atlanta, Georgia June 19-21, 1989 EPA/540/2-89/055

GLYCOLATE DECHLORINATION

Description

Dechlorination chemically removes chlorine from chlorinated organics such as polychlorinated biphenyls (PCBs) and dioxins. Polyethylene glycol (PEG), (a sodium or potassium-based reagent), is employed by the system. This process reduces the toxicity of materials but increases the volume. Dimethyl sulfoxide (DMSO), when added to the potassium polyethylene glycol (KPEG) process, can improve the extraction of dioxin from the organic phase into the immiscible aqueous reagent phase. The reagent reacts with the chlorinated organic and displaces a chlorine molecule to produce a lower toxicity, water-soluble material. The mechanism for dechlorination research indicates that the alkali metal, potassium, is substituted for sodium in order to improve reactivity. By-products of this process include chloride salts, polymers, and occasionally heavy metals.

Typically, the mixture is heated to reduce the viscosity of the reagent. Radio frequency or microwave heating is used for in situ heating, and preheating the reagent is typically used for a removal/treatment/disposal process. In situ dechlorination should be used for uniform, shallow, soil-contaminated areas in which conventional agricultural equipment can mix the soil and reagent. If, however, the contaminated soil is deeper than 1 to 2 feet or if high concentrations are apparent, it is more suitable to excavate the soil and then dechlorinate it after it is made into a slurry. One advantage of removing the soil to dechlorinate it is that the reagent can be recovered and recycled. This will eliminate some of the cost of removal, especially if larger amounts of reagent are required to dechlorinate the waste stream.

Applications

This process can be used to treat chlorinated organic compounds such as PCBs and dioxins, chlorinated hydrocarbons, and chlorinated acids and thiols. It can be used to treat wastewater, sludges, non-aqueous liquids, and soils.

Advantages and Disadvantages

This process will detoxify highly toxic compounds such as dioxins and PCBs.

Treatment is limited to wastes with less than 5,000 ppm PCBs. Concentrations greater than 5% chlorinated organics require excessive volume of reagent (low ppm is optimum). High moisture content (greater than 20%) may also require excessive reagent. High humic content in soil increases reaction time. Clay and sandy soils as well as high organic content soils can be treated with increased reaction time. There is no expected effectiveness for treatment of volatile organics, non-volatile metals, and volatile metals.

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Haztech News May 30, 1991 Carrier Oil Introduces PEG Chemistry Volume 6, No 11

US EPA September 1988 Technology Screening Guide for Treatment of CERCLA Soils and Sludges
EPA/540/2/88/004

GRAVIMETRIC PHYSICAL SEPARATION (TRU CLEAN™)

Description

TRU Clean™ is a proprietary soil washing system that uses a mechanically aquitaded gravimetric separator to reduce the volume of actinide-contaminated soils by concentrating the contaminants. A volume reduction of 80% has been achieved on plutonium-contaminated coral sands in a Johnson Atoll pilot plant. Volume reductions of up to 95% are projected after system improvements.

Applications

The process is applicable to soils and sludges contaminated with radionuclides. TRU Clean™ can operate on-site to decontaminate soils, reducing the volume of radioactive waste.

Advantages and Disadvantages

After processing, there is a volume reduction which may result in substantial cost savings in disposing of contaminated soil.

The primary disadvantage is that the process is based on a proprietary soil washing system, which would have to be purchased from a single supplier.

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INFRARED THERMAL TREATMENT

Description

The infrared thermal treatment process uses infrared radiation (IR, or heat) to volatilize organic constituents in a waste feed. The off-gas from the process is then treated by an afterburner and particulate and acid gas scrubbers. Different types of infrared electric furnaces are available. The type which has been most thoroughly demonstrated uses a moving woven wire belt to move the waste through a furnace. The furnace is heated by electric elements which generate radiant heat. The waste is spread on the belt in a layer approximately one inch thick. Objects fed to the infrared electric furnace should be less than two inches in diameter. Some waste materials will require pretreatment prior to feed to the furnace. In most applications, no combustion takes place in the furnace. Organics are volatilized, and possibly pyrolyzed, in the furnace and oxidized in the afterburner.

Applications

The infrared thermal treatment process is applicable to organic constituents in sludges and solids. Wastes containing large objects will require feed preparation prior to treatment in the infrared electric furnace. Because little excess air is used in the furnace, energy requirements of the infrared electric furnace are lower than for other thermal treatment technologies. Wastes containing metals may require treatment of solid residuals to immobilize the metals.

The process has a neutral effect on metals and radionuclides. The technology is not applicable to materials containing volatile metals.

Advantages and Disadvantages

The process is applicable to a wide variety of organic constituents. It is a developed, commercially available technology. The technology has relatively low operating costs compared with other thermal technologies because it has lower fuel consumption due to the smaller volume of off-gas generated. Off-gas cleanup costs are less in some cases because particulate carried out of the furnace is lower than other thermal technologies. The infrared electric furnace may be better suited for treatment of wastes containing semivolatile metals than other thermal methods because it operates at a lower temperature. It is likely that the infrared electric furnace may be successfully bench tested.

The technology has a neutral effect on most inorganics. It is not applicable to volatile metals. The technology may not be effective for some non-volatile or semivolatile organics.

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A Guide to Innovative Thermal Hazardous Waste Treatment Processes Hazardous Waste Consultant
November/December

IN SITU VITRIFICATION

Description

In situ vitrification (ISV) involves the electric melting of contaminated soils in place. Four electrodes, placed in a square pattern and at the desired depth, are used to electrically heat and melt contaminated soils and solids at temperatures up to 2000°C. Off-gases generated by the melting process are collected and treated prior to release. ISV breaks down organics and physically and chemically contains inorganics, heavy metals, and radionuclides.

The residuals of ISV are a monolithic, obsidian-like solid and the secondary waste from the off-gas system, which is incorporated into subsequent melts. Based on chemical and physical similarity with obsidian, durability is estimated at 18 million years. Delisting as a hazardous waste is probable and delisting as a TRU waste is possible because actinides are microencapsulated.

Application

This process is applicable to a wide variety of organic and inorganic contaminants located in the soil above the water table.

ISV requires the use of off-gas processing equipment that has limits relative to the amount of heat load and the volume of gases it can process. These limits are associated with the concentration of organics and other gas-generating materials that may be treated per unit time by the equipment. A rule-of-thumb organic concentration limit of 5 to 10 percent is used for initial application screening.

The presence of volatile metals such as mercury, makes the use of this process more complicated.

Advantages and Disadvantages

This process destroys waste organic contaminants and immobilizes inorganics. The process is commercially available.

Off-gasses are produced that require additional treatment.

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U S EPA September 1989 Forum on Innovative Hazardous Waste Technologies Domestic and International Atlanta, Georgia June 19-21, 1989 EPA/540/2-89/055

MAGNETIC SEPARATION

Description

Magnetic separation removes magnetic or recovers nonmagnetic materials. Magnetic separation can be accomplished on either wet or dry wastestreams. There are several types of separators that operate at various intensities, including belt, induced-roll, and drum. The force of the magnetic field is supplied by either electromagnets or permanent magnets. Utilizing a pretreatment can artificially convert nonmagnetic materials to magnetic materials. A V-shaped pole opposite a flat bar is the preferred method for producing a converging field. Drum separators are used for low-intensity magnetic separation. There are three types of drum separators: concurrent, counter-rotation, and counter-current. Concurrent drum separators extract an extremely clean magnetic concentrate from relatively coarse materials. It is often used in heavy medium recovery systems. The counter-rotation type is often utilized in roughing operations because it can handle occasional surges, hold magnetic material losses to a minimum, and can handle high solids loading. The counter-current drum separator is utilized in finishing operations. Typically, it operates on fine materials with particle sizes less than $250\text{ }\mu\text{m}$. Cross-belt separators are used on dry materials for low-intensity magnetic separation. This separator is used to concentrate moderately magnetic ores. A disc separator is a modified cross-belt separator that provides even greater selectivity.

Induced-roll separators are high-intensity separators. They are primarily used to separate magnetic materials from beach sands, wolframite, tin ores, glass sands, phosphate rock, and iron ores. One specific type of roll separator is the Permroll. Dry separation is utilized on materials with particles greater than $75\text{ }\mu\text{m}$.

Wet magnetic separators for high-intensity fields include induced roll machines and the Jones separator. One type of induced roll machine is the Gill, which has been effective for separating highly magnetic ilmenite from heavy mineral concentrates. The Jones separator is effective in separating fine hematite ores. Other applications of wet, high-intensity separators include separating magnetic particles from cassiterite concentrates, asbestos, scheelite concentrates, talc, flotation tailings, beach sand, and cyanidation residues.

Another magnetic separation process is Eddy-Current Separation. Eddy currents are currents that are induced in electrically conducting particles when exposed to a changing magnetic field. The interaction between the magnetic field and eddy-currents causes a force to be exerted on a conducting particle. The magnitude of this force is dependent upon the magnetic field, the currents and the motion of the particles relative to the magnetic field. If a mixture of conducting and non-conducting particles are passed over suitable magnetic fields, a different lateral particle deflection will result in the two types of particles being separated. Two eddy-current separators are the Ramp Separator and the Linear Motor

Applications

This technology will work with any waste containing magnetic particles that can be separated. The process can be used on water, slurries, soils, sludges, and sediments.

Removes particles with diameters as small as 1 micron. Flow rates are 100 times greater than ordinary filtration. When particles get below 0.5 cm, wet methods are utilized instead of dry methods. Eddy currents remove particles in the range of 1 to 4 in.

Advantages and Disadvantages

This process can reduce the volume of soils requiring further processing and/or treatment.

Disadvantages include the need for extensive materials handling and processing. Fugitive dust emissions is also a problem.

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PHYSICAL SEPARATION

Description

Soil contaminants are often found to be associated with particular size fractions of soils, most often the fine particle sizes. Fractionation of the soil based on particle size can, therefore, be an effective means of reducing the volume of the material that requires treatment. The processes effective for performing soil size fractionation include screening, classification, flotation, and gravity concentration (U S EPA 1988b).

Screening This process is the mechanical separation of materials based on their size. This separation is usually obtained using a uniformly perforated surface. The material is passed over the screen. The larger particles are retained on the surface and the smaller particles pass through. Screening is usually limited to particles larger than 250 μm in diameter (Perry and Chilton 1973).

Classification This process is used to separate particles based on their settling rate in a fluid, such as water. A single stage classifier will typically make a single separation, with faster settling materials going out the underflow and the slower going out the overflow. There are three types of classifiers: nonmechanical, mechanical, and hydraulic (Perry and Chilton 1973).

Flotation The injection of air into a liquid suspension can cause low-density solids and hydrocarbon solids to float to the surface for removal. This method is used extensively in the mining industry for concentration of minerals. Microbubbles formed by injection of air attach to particles, become trapped under larger particles, or become part of flocs. These particles with the attached air bubbles have a combined specific gravity less than that of water and float to the surface (Ives 1984).

Gravity Concentration This technique uses density differences of materials to effect separation. Gravity concentration can be implemented using sluices, shaking tables, and the traditional miner's pan. All of these devices keep the particles slightly apart so that they can move relative to each other and separate into layers of light and dense materials (Burt 1984).

Applications

Flotation and other physical separation techniques are used to recover copper, uranium, zirconium, and magnetite by the Palabora Mining Company in South Africa (Burt 1984). The method has also been used for removal of radium from uranium mill tailings in Elliot Lake (Raicevic 1970). During laboratory testing, flotation was found to reduce radium concentrations from 290 pCi/g to 57 pCi/g.

Several soil decontamination processes in the Netherlands use gravity concentration and flotation for removal of fine particles and organics from extracting agents (Assink 1985, U S EPA 1988b). Systems

similar to this are in the pilot-stage in the United States (Hazardous Waste Consultant 1989) Pilot plant testing at Rocky Flats in the early 1970s (Garnett et al 1980) showed that soils contaminated with 45, 284, and 7,515 pCi/g plutonium were reduced to 0.5, 12, and 86 pCi/g, respectively, using physical separation. The cleaned soil fraction ranged from 58 percent to 87 percent of the original volume.

Advantages and Disadvantages

Screening is an inexpensive method for separating particles, but screens are subject to plugging, which can greatly decrease their efficiencies. The use of dry screening generates dust emissions that must be controlled.

Classifiers have high continuous processing capabilities and are very reliable, but soils containing clay or sandy soils containing humus materials can be difficult to process.

Flotation can achieve very high separation rates if the materials are suited to such treatment, but it is a complex and expensive process.

Gravity concentration is a highly efficient and well proven technique, but it has a relatively low process capacity.

Wet processes may produce a liquid waste stream requiring treatment or disposal.

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POLYMERIZATION-POLYETHYLENE

Description

This process consists of mixing the waste with the liquid polyethylene (a thermoplastic) and allowing it to cool. This can be accomplished using several techniques including batch mixing and extrusion processing. Polyethylene is an organic polymer material of crystalline-amorphous structure, generally categorized as low, medium, or high density. Low density polyethylene (LPDE) is preferred over high density because of the ease of processibility.

Applications

This process is used to treat low level radioactively contaminated wastes. It can be used to treat sediment, soils, sludges, and slurries.

Advantages and Disadvantages

The process reduces the mobility of contaminants, but does not remove or destroy them.

The process results in increased volume of contaminant.

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ROTARY KILN INCINERATION

Description

A rotary kiln consists of an inclined, refractory lined, hollow cylinder which is rotated around its axis by an external drive mechanism. Material is fed into the kiln at the high end. The rotation of the kiln mixes the solids in the kiln and causes the solids to migrate to the low end of the kiln where they are removed. Rotary kilns are available in a variety of configurations, depending on the application and the nature of the feed material. Kilns may be fired co-currently (gas flow in the same direction as solids feed) or countercurrently. Operating temperatures may range from 1,400 to 2,000 degrees Fahrenheit for a normal operation, or from 2,200 to 2,500 degrees Fahrenheit for a slagging kiln. Combustion air and fuel (if required) are fed into one end of the kiln and off-gas is recovered from the other end. The off-gas requires treatment for control of emissions.

Applications

Rotary kiln incineration is applicable to organic constituents in a variety of waste matrices, including liquids, sludges and slurries, solids and gases. Slagging rotary kilns are applicable to solids with low softening point temperatures. Rotary kilns may be fired countercurrently to increase combustion zone turbulence, or co-currently to reduce particulate emissions. Some rotary kiln applications may require an afterburner in addition to off-gas treatment. Wastes containing metals may require treatment of solid residuals to immobilize the metals.

Rotary kiln incineration has a neutral effect on metals and non-volatile radionuclides. The technology is not applicable to materials containing volatile or semivolatile metals.

Advantages and Disadvantages

Rotary kiln incineration is applicable to a wide variety of organic constituents. It is a well understood, commercially available technology. Rotary kilns may be adapted for use with a wide variety of waste types.

The technology has a neutral effect on most inorganics. It is not applicable to volatile or semivolatile metals nor to wastes with low softening points. Operating costs are moderately high because wastes with little or no heating value require addition of supplemental fuel. Pilot testing is readily accomplished through a number of vendors, but bench testing is uncommon and of questionable value.

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U S EPA September 1989 Forum on Innovative Hazardous Waste Technologies Domestic and
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SLURRY PHASE BIOREACTOR

Description

This is a biological remediation process in which contaminated soils and/or sediments are mixed with water to form a slurry. This is done in an agitated reaction tank. Nutrient and air are added to the tank as necessary to facilitate the biological reactions.

After the contaminants have been destroyed, the slurry is pumped out of the reactor and sent to dewatering equipment. The remediated soil/sediment can be returned to the site. Water removed during the dewatering step can be reused for the next batch or sent to a treatment system.

Application

This process is applicable to soils and/or sediments that are contaminated with biodegradable organic compounds. The process could be operated either aerobically or anaerobically.

The process would not be effective for metals and radionuclides.

Advantages and Disadvantages

The process destroys the toxic contaminants, converting them into carbon dioxide, methane, water, and biomass.

This technology requires a considerable amount of materials handling equipment and solids dewatering equipment. Its potential economic advantage would only be realized if high initial concentrations of contaminants were present.

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International Atlanta, Georgia June 19-21, 1989 EPA/540/2-89/055

SOIL WASHING

Description

Soil washing is based on the principle of contaminant removal from soil by washing with a solution. Washing agents can include water, acids, surfactants, solvents, or chelating agents. Contaminated soil is excavated and placed in a reactor for mixing with the extracting solution. Sorbed contaminants are transferred to the liquid phase by dissolving, by forming an emulsion, or by a chemical reaction with the solution. When extraction is complete, the soil particles are physically separated from the solution, and the treated soil can be returned to the excavation. The extractant containing the contaminants requires further treatment for recycling or disposal.

Applications

By selecting the appropriate washing solution, soil washing technology can potentially be used to treat inorganics, metals, organics, or radionuclides in soil. Application of a soil washing reactor system at four sites in the Netherlands demonstrated greater than 80 percent removal efficiencies for polynuclear aromatic hydrocarbons (PNAs), cyanides, heavy metals, mineral oil, and halogenated hydrocarbons (Assink 1985). Soil structure and chemistry are important variables in applying the technology successfully and require evaluation on a site-by-site basis.

Inorganics that can be washed from soil with water include soluble salts such as carbonates of nickel, zinc, and copper. Dilute solutions of sulfuric, hydrochloric, nitric, phosphoric, and carbonic acid have been widely used in industry to extract metal ions by dissolving basic metal salts including hydroxides, oxides, and carbonates. Heavy metals can be removed from soils by complexing and chelating agents such as citric acid, ethylenediaminetetraacetic acid (EDTA), and diethylenetriaminepentaacetic acid (DTPA) (U S EPA 1985, 1987c). Arsenic and selenium removal can be enhanced with the addition of oxidizers such as hydrogen peroxide (U S EPA 1986a).

Organics that can be removed from soil by water washing include low to medium molecular weight aldehydes, ketones, and aromatics and lower molecular weight hydrocarbons such as trichloroethylene and tetrachloroethylene. Other basic organic groups like amines, ethers, and anilines can be flushed from soil by washing with an acidic solution. Surfactants have been employed to enhance the recovery of petroleum products and PCBs (U S EPA 1985). Removal of organochlorine compounds by extraction with a solvent mixture of toluene, kerosene, and octanol was demonstrated in laboratory experiments on sludges from Rock Mountain Arsenal (A.D. Little 1988).

The use of water, inorganic salts, mineral acids, and complexing reagents to extract radionuclides from soils and tailings was reviewed by the EPA (U S EPA 1988b). These extraction techniques have been applied as bench-scale or pilot-plant testing for removal of radium and thorium but have not been

implemented for remediation of a radiologically contaminated site. Water was shown to be ineffective, removing only 10 percent of the radium and virtually none of the thorium from soils tested. Inorganic salt solutions, mineral acids, and complexing reagents all showed high removal percentages in some applications (U S EPA 1988b).

Advantages and Disadvantages

The primary advantage of soil washing is that a variety of types of contaminants can potentially be removed from soils in a reactor under relatively controlled conditions. The process is flexible and can be designed for specific mixtures of contaminants, although treatment of mixtures may require multiple stages using different washing solutions.

Contaminants are not destroyed but are transferred to the aqueous phase. The technology requires a subsequent separation process for liquids and solids and treatment of the resulting solution for recycling or disposal. Soil washing may require the addition of potentially hazardous substances as washing agents. Residual soil washing chemicals remaining in the soil may also be a problem.

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Superfund Sites EPA/540/2-88/002 August 1988

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EPA/540/5-89/013

SOLAR

Description

A system that uses solar energy to destroy hazardous organic wastes is being developed by VEDA Inc of Alexandria, Virginia. The heart of this system is an array of sun-tracking mirrors as heliostats, referred to as a unified heliostat array. Each heliostat concentrates and reflects the sun's radiant energy to a windowed reactor vessel. The heat and UV radiation provided by the unified heliostat array are used to destroy the organic contaminants.

A system for processing PCB or dioxin contaminated soil includes a desorption reactor, which heats the soil to 750°F. The high temperature vaporizes the organic contaminants from the soil. The heat for the desorption reactor is provided by cooling air from the windowed reactor.

The vaporized contaminants from the desorption reactor are injected into the windowed reactor where they are irradiated through a quartz window with concentrated solar energy from the unified heliostat array. The reactor temperature is maintained at 1,300°F (700°C) and is controlled by air flow around the reactor's ceramic liner. Inside the windowed reactor, organic compounds are decomposed by the high temperature and UV radiation. Some of the resulting exhaust gas is recirculated through the desorption reactor to provide additional heat needed to raise the temperature of the contaminated soil. The remainder of the exhaust gas is treated in a scrubber to remove hydrogen chloride, sulfur dioxide, and particulates before it is discharged to the atmosphere.

Applications

This process is applicable to soils and sediments that are contaminated with volatile and semivolatile organics. The process may also be applied to aqueous streams.

Advantages and Disadvantages

The process offers high destruction efficiencies for organic contaminants. Efficiencies as high as 99.9999% have been achieved.

The system is not commercially available. However, a prototype system designed to process 500 pounds of contaminated soil per hour is being developed. Additional research is in progress to determine the temperature and condition necessary to volatilize and desorb PCBs and dioxins from soil.

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A Guide to Innovative Thermal Hazardous Waste Treatment Processes VEDA Solar Destruction
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Solar Detoxification is Closing in on Commercial Phase U S Water News Volume 8, No 5
November 1991

SOLIDIFICATION/STABILIZATION TECHNOLOGIES

Description

Solidification is a process that mechanically binds contaminants to the solidification agents to reduce the contaminant mobility. The process produces a solid matrix of waste with high structural integrity. Stabilization usually involves the addition of a chemical reagent to react with the contaminant producing a less mobile or less toxic compound. Solidification and stabilization are usually used together to immobilize a waste. Two major forms of solidification/stabilization, pozzolanic-based and cement-based, have been used extensively to treat hazardous waste (U S EPA 1985, 1986d). More innovative solidification/stabilization technologies include mixing with organic polymers and asphalt.

Pozzolanic-Based This solidification method uses materials that form a solid mass when mixed with hydrated lime. Pozzolanic materials include diatomaceous earth, blast-furnace slag, ground brick, and some fly ashes. After mixing of the waste and pozzolan, hydrated lime is blended into the mixture. The resulting moist mixture is packed into a mold and allowed to cure.

Cement-Based Cements are often used as binding agents, along with pozzolanic materials, to improve the strength and chemical resistance of solidified waste. The types of cement used for solidification can be selected to emphasize a particular cementing reaction. Portland cement has been commonly applied to stabilization of metals. Masonry cement has been tested for stabilization of radionuclides.

Polymer Based Various organic polymers to produce a stable matrix for stabilizing and solidification of wastes. This method is innovative. Polymer materials which have been applied include epoxies and polyesters.

Asphalt Based The waste may be stabilized by mixing with bitumen a mixture of high molecular weight asphaltene and malthene hydrocarbons.

Applications

Solidification/stabilization is being used for low-level radioactive and RCRA mixed wastes at the Hanford nuclear reservation (Sferrazza 1990). After mixing the wastes with portland cement, fly ash, and clay, the cemented wastes are poured into specially constructed near-surface concrete vaults that isolate the cement product from the environment (Collins 1988). The combination of waste solidification and placement in concrete vaults is designed to contain the waste materials for at least 10,000 years.

Record of Decision (ROD) documents for at least seven Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites have identified solidification/stabilization as the remedial technology of choice for immobilization of heavy metal contaminants. These sites include the Selma Pressure Treating Company, CA, Flowood, MS, York Oil, NY, Chemtronics, NC, Bailey Waste Disposal, TX, Mid-State Disposal Landfill, WI, and Love Canal, NY.

Various solidification/stabilization techniques have been used at DOE sites throughout the United States. The 513 Solidification Unit at Lawrence Livermore National Laboratory uses cement, Envirostone™, Petroset™, and Aquaset™ to solidify liquid wastes. The Los Alamos National Laboratory uses an in-drum solidification technique for immobilization of TRU solid and liquid wastes. Plutonium precipitation sludge is immobilized in-drum at Mound using portland cement. The Oak Ridge Facility uses a fly ash cement to immobilize a treatment pond sludge containing uranium, chromium, nickel, cadmium, and technetium. Portland cement is used to immobilize waste sludge in Rocky Flats pondcrete and saltcrete processes (Sferrazza 1990).

Advantages and Disadvantages

Solidification/stabilization is a well established process for reducing the mobility and toxicity of hazardous wastes. Solid wastes containing radioactive contaminants are well suited for this process as it contains and reduces the mobility of the radioactive materials. Solidification/stabilization processes increase the volume of the treated wastes. Organic compounds, if present, often interfere with the desired solidification and stabilization process.

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SURFACTANT WASHING

Description

Surfactant washing is based on the principle of contaminant removal from soil by washing with a surfactant solution. Contaminated soil is excavated and placed in a reactor for mixing with the solution. The surfactant, which is soluble in both the contaminant and water, removes the contaminant from the soil and transfers it to the solution.

When the washing process is complete, the soil particles are physically separated from the solution, and the treated soil can be returned to the excavation.

Applications

This process has been used to treat soil contaminated with petroleum products, organics, and PCBs.

Advantages and Disadvantages

This may be a cost effective method to reduce the volume of contaminated material into a small volume of liquid. This technology is still at the innovative stage of development.

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VITRIFICATION

Description

Vitrification of wastes involves combining the wastes with molten glass at a temperature of 1,350°C or greater. However, the encapsulation might be done at temperatures significantly below 1,350°C (a simple glass polymer such as boric acid can be poured at 850°C). This melt is then cooled into a stable, noncrystalline solid (U S EPA 1985).

One variation on this process is in situ vitrification (ISV) in which wastes and soils or sludges are melted in-place to bind the waste in a glassy, solid matrix resistant to leaching. In the ISV process, four electrodes are inserted into the soil to the desired depth. A glass frit is placed between the electrodes to act as a starter path for the initial melt to form. As the melt grows downward and outward, it incorporates non-volatile elements and destroys organic components by pyrolysis. The pyrolyzed by-products migrate to the surface of the melted zone where they combust in the presence of oxygen. Inorganic materials are dissolved into or are encapsulated in the melt. Convective currents within the melt uniformly mix materials that are present in the soil. When the electric current ceases, the molten volume cools and solidifies into a vitrified mass. A hood placed over the processing area provides confinement for the combustion gases, drawing the gases into an off-gas treatment system.

Applications

Vitrification is best used for soils with a high concentration of contaminants or with contaminants that must be completely immobilized (such as radioactive species). To be considered for vitrification, the wastes should be either stable or totally destroyed at the process temperature (U S EPA 1985).

In situ vitrification will work with fully saturated soils, however, the water in the soil must be evaporated before the soil will begin to melt. Soils with permeabilities greater than 10^{-4} cm/sec are difficult to vitrify in the presence of flowing groundwater and, therefore, some type of groundwater diversion may be necessary. If buried metals, such as drums, occupy over 90 percent of the linear distance between electrodes, a conduction path that leads to electrical shorting between electrodes may result.

Several vitrification facilities for treatment of radioactive wastes are currently under development. The Hanford Waste Vitrification Plant is designed to fuse high-level radioactive mixed wastes into a glass product. The facility was expected to be completed by mid-1991. The Defense Waste Processing Facility will use vitrification for the immobilization of high-level waste from the Savannah River Site. This facility is almost complete, with cold testing scheduled for September 1990 and hot start-up planned for January 1992. The West Valley Nuclear Services Co. has constructed a vitrification system as part of the West Valley Demonstration Project. The vitrification system has completed a 5-year period of testing.

using simulated wastes and is currently being renovated. West Valley is preparing a Part A Radioactive Mixed Hazardous Waste permit for the facility (Sferrazza 1990)

The Idaho National Engineering Laboratory is evaluating the feasibility of using in situ vitrification for treatment of buried wastes at this facility. The process has undergone laboratory and engineering scale tests at the Pacific Northwest Laboratory, where the equipment was developed, and has been applied once at the Idaho National Engineering Laboratory on a small test area. Starting in 1992, three larger scale tests are planned (Sferrazza 1990)

Advantages and Disadvantages

The primary advantage of vitrification is that it effectively immobilizes non-volatile species in a solid that is very durable and resistant to leaching. Disadvantages of this technology are related to its high cost, which is the result of the large amount of power that is required to melt the glass or soil and the need for specialized equipment and trained personnel (U S EPA 1985). The presence of high moisture content or high organics may also hinder operation. Significant concentrations of combustible gases may also produce a safety hazard. This process may need an off-gas collection and treatment system for volatile and semivolatile organics and volatile metals.

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WET AIR OXIDATION

Description

Wet air oxidation is a thermal treatment technology that breaks down (by oxidation) suspended and dissolved inorganic and organic materials in a high-temperature, high-pressure, aqueous environment. Waste is combined with compressed air (the oxidizing agent), passes through the cold side of the heat exchanger, and enters a reactor where exothermic reactions elevate the temperature and pressure of the mixture to a desired value. Oxygen in the air reacts with oxidizable material in the waste. In the heat exchanger, the raw waste and air mixture is heated to reaction conditions by an indirect heat exchange with the hot-oxidized effluent. In cases where the heat of reaction is insufficient to maintain the design operating temperature, additional heat may be necessary.

After exiting the reactor, the waste air mixture enters the heat up side of the heat exchanger and is directed to the separator. The spent process vapors (noncondensable gasses) are separated from the oxidized liquid phase and are directed into a two-stage water scrubber-carbon bed absorber, vapor treatment system.

Organic substances are oxidized to yield highly oxygenated products and water. Organic carbon-hydrogen compounds oxidize to carbon dioxide and water, organic sulfur compounds and inorganic sulfides oxidize to inorganic sulfate, inorganic and organic cyanides oxidize to carbon dioxide, ammonia, or molecular nitrogen. Nitrogen oxides such as NO or NO₂ are not formed in wet air oxidation because reaction temperatures are not high enough.

The process has been tested on phenolic wastes, organic sulfur wastes, general organic wastes, cyanide wastes, pesticide wastes, and solvent still-bottom wastes. Operating condition ranges are 175-600 C, and 2-200 atm. Catalysts may be used to enhance oxidation, especially of chlorinated aromatics. The oxidation reaction is usually self-sustaining due to the exothermic oxidation reactions. Wet air oxidation is a very specialized process not currently used on hazardous wastes to any great extent. However, it has been used commercially to regenerate spent powdered carbon from biological treatment systems.

Applications

The process is applicable to organics, including phenolic and organic sulfur wastes, petroleum refinery spent caustic wastewater, cyanide waste, pesticide waste, solvent still-bottoms waste, and general organic waste. Contaminants treated by the Zimpro/Passavant (vendor) process include inorganic and organic cyanides, aliphatic and chlorinated aliphatic compounds, and aromatic and halogenated aromatic compounds.

Advantages and Disadvantages

A primary advantage of this process is that it destroys the applicable contaminants rendering them harmless to the environment. It is effective on a wide range of contaminants and may offer economic advantages in specific cases.

The process is complex and requires high operating temperatures and pressures. Expensive equipment is required, as well as highly trained operators.

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APPENDIX D
STATEMENTS OF WORK FOR TECHNOLOGIES
SELECTED FOR TREATABILITY TESTS

APPENDIX D
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OZONATION

Introduction

This statement of work covers the bench-scale testing of the Ozonation process to destroy PCBs in surface water at RFP. The review of existing site characterization data indicates the concentration of the PCB Aroclor-1254 exceeds ARARs for surface water at two or more OUs. This species is potentially amenable to treatment by oxidation using ozone. Treatability testing will be performed on site at the RFP or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of the ozone oxidation process for destruction of PCBs in water. The test will evaluate the percent destruction of PCBs which can be achieved in comparison to the likely effluent concentration which would be required for discharge of treated waters to surface water or to a sewage treatment system. The dependence of destruction efficiency on ozone dose, residence time and vessel configuration and mixing properties will be investigated.

Test Approach

The test program will use a small bench scale oxidation reactor to run batch tests on samples of PCB contaminated water. Ozone will be used as the oxidant at a number of different concentrations. Tests will be run at different mixing conditions. The water will be sampled at the start of the test and at multiple time intervals during the course of the test. These samples will be chemically analyzed to determine PCB destruction and the presence of any intermediates.

POTASSIUM FERRATE PRECIPITATION

Introduction

This statement of work covers the bench-scale testing of the Potassium Ferrate Precipitation (TRU/Clear™) process to remove radionuclides from surface water and groundwater at RFP. TRU/Clear™ is the brand name for a proprietary precipitating agent based on the use of ferrate ions. The review of existing site data indicates that total gross alpha emitters such as uranium, plutonium, and americium are present in groundwaters and surface waters at RFP in concentrations which exceed possible action levels. All of these species are potentially amenable to treatment using TRU/Clear™. Treatability testing will be performed on site at the RFP or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies and handle radioactive materials.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of the use of TRU/Clear™ in removal of radionuclides from water. The tests will also have the objective of establishing the correct dosage and operating pH for the use of TRU/Clear™ and to determine the removal efficiencies which can be obtained by a combination of addition of TRU/Clear™ with either solids settling or filtration.

Test Approach

The test program will use small bench scale tests to remove the radionuclides using TRU/Clear™. Initial testing will involve multiple jar tests using different dosages of TRU/Clear™ at a number of different pH levels. In one round of tests the solids will be allowed to settle and the supernatant water analyzed for radionuclides to determine removal efficiencies. In a second round of tests the samples will be filtered and the filtered water analyzed for radionuclides again to determine removal efficiencies. The most effective operating conditions for the TRU/Clear™ process will be established in this fashion.

SLURRY PHASE BIOREACTOR

Introduction

This statement of work covers the pilot-scale testing of the slurry phase bioreactor process to destroy PCBs in soils at RFP. The review of existing site characterization data indicates the concentration of the PCB Aroclor-1254 exceeds ARARs for soils at two or more OUs. This species is potentially amenable to treatment by biological degradation using slurry phase bioreactors. Treatability testing will be performed on site at the RFP or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of the slurry phase biological process for destruction of PCBs in soil. The test will evaluate the percent destruction of PCBs which can be achieved in comparison to the likely cleanup levels for placement of the soil back on site or disposal at a landfill. Aerobic and anaerobic biological processing will likely be investigated. The dependence of destruction efficiency on nutrient and oxygen addition, residence time and vessel configuration and mixing properties will be investigated.

Test Approach

The test program will use a pilot scale biological reactors to run tests on samples of PCB contaminated soil. Tests will be run under aerobic and anaerobic conditions at different levels of nutrient addition and mixing conditions. The soil will be sampled at the start of the test and at multiple time intervals during the course of the test. These samples will be chemically analyzed to determine PCB destruction and the presence of any intermediates.

ULTRAVIOLET OXIDATION

Introduction

This statement of work covers the bench-scale testing of the UV Oxidation process to destroy PCBs in surface water at RFP. The review of existing site characterization data indicates the concentration of the PCB Aroclor-1254 exceeds ARARs for surface water at two or more OUs. This species is potentially amenable to treatment by UV oxidation. Treatability testing will be performed on site at the RFP or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of the UV oxidation process for destruction of PCBs in water. The test will evaluate the percent destruction of PCBs which can be achieved in comparison to the likely effluent concentration which would be required for discharge of treated waters to surface water or to a sewage treatment system. The use of the potential oxidation agents hydrogen peroxide and ozone will be investigated and the dependence of oxidizing agent dose on destruction efficiency will be investigated. The removal efficiency dependency on UV wavelength and intensity will be investigated as well as the dependence on residence time and vessel configuration and mixing properties. The potential for fouling of the UV lamp will be investigated as well as the formation of toxic intermediates.

Test Approach

The test program will use a small bench scale UV photolysis reactor to run batch tests on samples of PCB contaminated water. Hydrogen peroxide and ozone will be used as oxidants at a number of different concentrations. Tests will be run at varying UV wavelengths and intensities and under different conditions of mixing. The water will be sampled at the start of the test and at multiple time intervals during the course of the test. These samples will be chemically analyzed to determine PCB destruction and the presence of any intermediates.

ULTRAVIOLET PHOTOLYSIS

Introduction

This statement of work covers the bench-scale testing of the UV photolysis process to destroy PCBs in surface water at RFP. The review of existing site characterization data indicates the concentration of the PCB Aroclor-1254 exceeds ARARs for surface water at two or more OUs. This species is potentially amenable to treatment by UV photolysis. Treatability testing will be performed on site at the RFP or at an off-site laboratory possessing the necessary licenses, approvals, and notifications to perform hazardous waste treatability studies.

Test Objectives

The primary objective of this testing will be to evaluate the effectiveness of the UV photolysis process for destruction of PCBs in water. The test will evaluate the percent destruction of PCBs which can be achieved in comparison to the likely effluent concentration which would be required for discharge of treated waters to surface water or to a sewage treatment system. The removal efficiency dependency on UV wavelength and intensity will be investigated as well as the dependence on residence time and vessel configuration and mixing properties. The potential for fouling of the UV lamp will be investigated as well as the formation of toxic intermediates.

Test Approach

The test program will use a small bench scale UV photolysis reactor to run batch tests on samples of PCB contaminated water. Tests will be run at varying UV wavelengths and intensities and under different conditions of mixing. The water will be sampled at the start of the test and at multiple time intervals during the course of the test. These samples will be chemically analyzed to determine PCB destruction and the presence of any intermediates.